9-1-2020

Mapping geographical inequalities in access to drinking water and sanitation facilities in low-income and middle-income countries, 2000-17

Ali S. Akanda
University of Rhode Island, akanda@uri.edu

et al

Citation/Publisher Attribution

Akanda, Ali S., and et al. "Mapping geographical inequalities in access to drinking water and sanitation facilities in low-income and middle-income countries, 2000-17." *The Lancet Global Health* 8, 9 (2020): e1162-e1185. doi:10.1016/S2214-109X(20)30278-3.

Mapping geographical inequalities in access to drinking water and sanitation facilities in low-income and middle-income countries, 2000–17

*Local Burden of Disease WaSH Collaborators**

Summary

Background Universal access to safe drinking water and sanitation facilities is an essential human right, recognised in the Sustainable Development Goals as crucial for preventing disease and improving human wellbeing. Comprehensive, high-resolution estimates are important to inform progress towards achieving this goal. We aimed to produce high-resolution geospatial estimates of access to drinking water and sanitation facilities.

Methods We used a Bayesian geostatistical model and data from 600 sources across more than 88 low-income and middle-income countries (LMICs) to estimate access to drinking water and sanitation facilities on continuous continent-wide surfaces from 2000 to 2017, and aggregated results to policy-relevant administrative units. We estimated mutually exclusive and collectively exhaustive subcategories of facilities for drinking water (piped water on or off premises, other improved facilities, unimproved, and surface water) and sanitation facilities (septic or sewer sanitation, other improved, unimproved, and open defecation) with use of ordinal regression. We also estimated the number of diarrhoeal deaths in children younger than 5 years attributed to unsafe facilities and estimated deaths that were averted by increased access to safe facilities in 2017, and analysed geographical inequality in access within LMICs.

Findings Across LMICs, access to both piped water and improved water overall increased between 2000 and 2017, with progress varying spatially. For piped water, the safest water facility type, access increased from 40·0% (95% uncertainty interval [UI] 39·4–40·7) to 50·3% (50·0–50·5), but was lowest in sub-Saharan Africa, where access to piped water was mostly concentrated in urban centres. Access to both sewer or septic sanitation and improved sanitation overall also increased across all LMICs during the study period. For sewer or septic sanitation, access was 46·3% (95% UI 46·1–46·5) in 2017, compared with 28·7% (28·5–29·0) in 2000. Although some units improved access to the safest drinking water or sanitation facilities since 2000, a large absolute number of people continued to not have access in several units with high access to such facilities (>80%) in 2017. More than 253000 people did not have access to sewer or septic sanitation facilities in the city of Harare, Zimbabwe, despite 88·6% (95% UI 87·2–89·7) access overall. Many units were able to transition from the least safe facilities in 2000 to safe facilities by 2017; for units in which populations primarily practised open defecation in 2000, 686 (95% UI 664–711) of the 1830 (1797–1863) units transitioned to the use of improved sanitation. Geographical disparities in access to improved water across units decreased in 76·1% (95% UI 71·6–80·7) of countries from 2000 to 2017, and in 53·9% (50·6–59·6) of countries for access to improved sanitation, but remained evident subnationally in most countries in 2017.

Interpretation Our estimates, combined with geospatial trends in diarrhoeal burden, identify where efforts to increase access to safe drinking water and sanitation facilities are most needed. By highlighting areas with successful approaches or in need of targeted interventions, our estimates can enable precision public health to effectively progress towards universal access to safe water and sanitation.

Funding Bill & Melinda Gates Foundation.

Lancet Glob Health 2020; 8: e1162–85

*Collaborators listed at the end of the Article

Correspondence to:
Dr Robert C Reiner Jr, Institute for Health Metrics and Evaluation, Department of Health Metrics Science, School of Medicine, University of Washington, Seattle, WA 98121, USA
bcreiner@uw.edu

Introduction

WHO's Integrated Global Action Plan for the Prevention and Control of Pneumonia and Diarrhoea emphasises the need for preventive measures.[1] Unsafe water and unsafe sanitation were the first and second leading risk factors for under-5 mortality from diarrhoeal diseases globally in 2017.[2] These risks increase susceptibility to the spread of infectious agents that cause diarrhoea, including rotavirus and *Vibrio cholerae*.[3–6] They are also linked to the spread of neglected tropical diseases (NTDs),[7–10] and adverse outcomes such as stunting, wasting, and underweight.[11–13] Low access to safe water and sanitation has also been linked to broader social outcomes such as reductions in school attendance (particularly for girls who are menstruating), losses to economic productivity, and undue burden on women of time spent collecting water.[14,15]

Access to safe drinking water and sanitation are human rights,[16] conferring benefits to human wellbeing beyond their impact on health. The global health and development

Research in context

Evidence before this study

In light of the health risks associated with unsafe drinking water and sanitation, as well as broader considerations of human development, the Sustainable Development Goals (SDGs) included the target of universal access to safe facilities by 2030. The WHO and United Nations Children's Fund (WHO–UNICEF) Joint Monitoring Programme estimates access to water and sanitation nationally and by urban and rural areas, while the Global Burden of Diseases, Injuries, and Risk Factors (GBD) study quantifies the health risks posed by unsafe water and sanitation nationally and for subnational regions in select countries. Although these and other efforts provide valuable insights, they mask local and cross-boundary variation and ultimately result in an incomplete picture of areas in greatest need of intervention. The limited availability of accurate and wide-ranging estimates monitoring local geographical inequalities presents a barrier to achieving universal access to safe water and sanitation facilities. Studies have used model-based geostatistics to map various health and sociodemographic factors, highlighting the potential to apply these methods for mapping access to water and sanitation across low-income and middle-income countries (LMICs).

Added value of this study

To our knowledge, this study presents the first high-resolution subnational estimates of access to safe drinking water and sanitation facilities across more than 88 LMICs and across all indicators of access from 2000 to 2017. Our Bayesian geostatistical models and extensive geolocated dataset account for spatial and temporal trends, and our suite of highly resolved spatial covariates leverage the relationships between access to water and sanitation and other variables for improved estimation. Additionally, this is the first application of ordinal regression methods on water and sanitation data at large spatial scales, allowing us to appropriately account for the mutually exclusive and collectively exhaustive (ie, accounting for 100% of the population) relationships between the relevant indicators of access. We report increasing access to safe facilities over time, but trends varied regionally, and many people continued to have no access to safe drinking water and sanitation facilities in 2017 across the LMICs studied. We estimate that 143 300 (95% uncertainty interval 126 100–163 000) deaths of children younger than 5 years were attributable to unsafe water in sub-Saharan Africa in 2017, yet increases in access to safe water averted more than 18 100 (15 700–21 200) child deaths in the region in that year. Averted child deaths were concentrated in select units that had great progress in access, while child diarrhoeal mortality increased in other units, probably due in part to decreases in access to piped water. Although geographical inequality decreased in most LMICs from 2000, in some cases the lowest level of access remained unchanged, effectively leaving behind some units, even as progress was made nationally.

Implications of all the available evidence

Despite considerable progress since 2000, geographical inequalities remain an obstacle to reaching the SDG target of universal access to safely managed facilities. Our estimates highlight where the most substantial improvements were achieved over time, identifying areas with successful strategies for adaptation elsewhere. Our identification of areas in which access to safe facilities is low, combined with high-resolution estimates of high diarrhoeal burden and child malnutrition prevalence, calls attention to communities with high susceptibility to the spread of infectious diseases. Although access to safe facilities is increasing in many countries, subnational inequalities point to the need for targeted interventions, particularly to reach communities with the lowest access and to increase access to the safest facility types. Our findings can inform local level monitoring of progress towards the SDG target, and provide a resource for decision makers to target areas most in need of additional resources.

community has prioritised access by including safe water and sanitation targets in both the Millennium Development Goals and more recently in the Sustainable Development Goals (SDGs), in which the UN called for access to be universal (ie, 100% access) and equitable. Despite substantial expansion of access during the Millennium Development Goals era, it has been previously estimated that less than 75% of the population in many countries in sub-Saharan Africa and south and southeast Asia had access to improved facilities in 2017.[17]

Previous estimates of access have been reported primarily at the national level, as well as at the subnational level across Africa and for a subset of other countries.[2,17–23] The WHO and United Nations Children's Fund (WHO–UNICEF) Joint Monitoring Programme (JMP) has analysed inequality of access by wealth quintile and urban-rural status, as well as within subnational regions for select locations.[24,25] These analyses, however, do not provide comprehensive estimates over space and time across low-income and middle-income countries (LMICs) at fine spatial scales. Understanding variation in water and sanitation access in second administrative-level units (eg, districts, counties; henceforth termed units) is imperative to identifying low-access areas at heightened risk of disease transmission,[26,27] and areas that have successfully achieved high levels of access. Previous studies have used model-based geostatistics to map health indicators such as under-5 mortality,[27] diarrhoea incidence and prevalence,[28] and child growth failure,[29] along with sociodemographic factors such as educational attainment,[30] and interventions such as insecticide-treated bednet coverage[31] and childhood vaccines.[32] We aimed to extend these methods to estimate access to safe drinking water and sanitation facilities at fine spatial resolutions.

Methods

Overview

To produce a comprehensive baseline of comparable estimates, we leveraged the indicators used by the JMP[24] and the Global Burden of Disease (GBD) study[2] with a Bayesian geostatistical model. With use of data from 600 unique datasets, we produced estimates of the relative (proportion) and absolute (number of people) access to water and sanitation facilities across continuous geographical surfaces and aggregated resulting predictions to national and subnational levels (reported as second administrative-level units) in more than 88 LMICs from 2000 to 2017. We modelled access by facility-type indicators and for specific facilities with an ordinal modelling framework. We report regional results according to the GBD 2017 geographical hierarchy.[2] We highlight specific types of transitions made in access to facility types and report the number of child diarrhoeal deaths attributed to unsafe facilities and averted by increased access to safe facilities. Finally, we present an analysis of variation in subnational geographical inequality in access.

Study design

We generated estimates for two sets of four mutually exclusive and collectively exhaustive indicators of access—one set for drinking water and one for sanitation—with uncertainty intervals (UIs), from 2000 to 2017. Each set of four indicators collectively accounts for 100% of the population in the respective geographical area. We used an ordinal regression framework in which each indicator was modelled using an ensemble modelling framework for each country individually. We produced subnational-level estimates for 88 LMICs for water and 89 LMICs for sanitation, first estimating continent-wide surfaces at a resolution of approximately 5×5 km, and then aggregating to second and first administrative and national boundaries. We included low, low-middle, and middle development countries, as classified by their Socio-demographic Index quintile,[33] an indicator based on education, fertility, and income (appendix p 94). Despite their relatively high Socio-demographic Index, China and Libya were included to maintain geographical continuity. Countries were excluded if sufficient data were not available for reliable estimation with use of our modelling paradigm. A complete list of the countries included is available in the appendix (p 94). This study complied with the Guidelines for Accurate and Transparent Health Estimates Reporting (appendix p 93).[34] Further details on methods and software used are available in the appendix (pp 9–11).

Data

Data were collated from Demographic and Health Surveys, Multiple Indicator Cluster Surveys, and other household surveys and censuses across 88 countries for water and 89 for sanitation from 2000 to 2017 (inclusion criteria details in appendix p 6). We used data from 600 unique sources—501 for water and 457 for sanitation (some sources contained both water and sanitation data). For water, 60·2% of our data by weighted sample size comprised geopositioned points, and 69·3% of weighted sanitation data were points. All other data were areal data. Drinking water facilities were categorised as piped (piped on or off premises), other improved (protected wells and springs, bottled water, rainwater collection, bought water), unimproved (unprotected wells and springs), or surface water (figure 1). Sanitation facilities were categorised as sewer or septic (sewer or septic tanks), other improved (improved latrines, ventilated improved latrines, composting toilets), unimproved (flush toilets to open channels, unimproved latrines), or open defecation (figure 1), using standardised definitions from the JMP.[17,24] The resulting schema yielded mutually exclusive and collectively exhaustive indicators for water and sanitation access.[17]

Statistical analysis

To account for the ordinal data structure of the indicators of access for water (piped, other improved, unimproved, and surface water) and sanitation (sewer or septic, other improved, unimproved, and open defecation), this analysis used an ordinal continuation-ratio modelling strategy.[35] This approach allows for the simultaneous modelling of mutually exclusive categorical responses, as shown in similar geospatial analyses.[30,32] We first modelled the proportion of the population with access to sewer or septic sanitation using a binomial model. We then modelled the proportion of the population with access to other improved sanitation conditioned on not having access to sewer or septic sanitation. Subsequently, we modelled the proportion with access to unimproved sanitation conditioned on not having access to sewer or septic sanitation or other improved sanitation. The estimates from the second and third conditional models were then combined with the estimates from the first to generate a full set of estimates of access for all four indicators. In this manner, the estimates and their associated uncertainty incorporate the mutually exclusive and collectively exhaustive data structure. The same approach was used for the set of four indicators of access to drinking water facilities.

See Online for appendix

For each model used in this strategy, we used an ensemble modelling approach. Applying a stacking ensemble modelling approach, the data were initially fit with seven gridded-raster covariates (appendix p 28) to three independent models using a generalised additive model, boosted regression trees, and lasso regression. This generalised stacking approach has been successfully used in similar geospatial analyses of health and social data to optimise predictive performance.[30,32] Predictions were generated from each of these child models to create raster

Facility types (water)	Indicators		
Piped water to inside household or to yard	Piped on premises	Piped	Improved
Piped water to neighbour's household, public stand pipe	Piped off premises		
Protected well, protected spring, rainwater, bottled water, tanker truck	Other improved		
Unprotected well, unprotected spring	Unimproved		
River, lake, canal, dam, surface water	Surface water		

Facility types (sanitation)	Indicators		
Sewer	Sewer	Sewer or septic	Improved
Septic tank	Septic		
Improved latrines, ventilated improved latrines, compost toilets	Other improved		
Unimproved latrines, bucket, hanging toilet	Unimproved		
No facility, bush	Open defecation		

Figure 1: **Access to drinking water and sanitation indicators**
The mutually exclusive and collectively exhaustive indicators modelled for water and sanitation. Each set of indicators collectively account for 100% of the population in the respective geographical area. The water indicators (piped on premises or piped off premises [piped], other improved, unimproved, and surface water) and the sanitation indicators (sewer or septic, other improved, unimproved, and open defecation) are outlined along with each indicator's corresponding facility types. Facility types are categorised into the standardised indicators as defined by the WHO–UNICEF Joint Monitoring Programme to ensure concordance with global monitoring targets and comparability across locations.

covariates to be used in the parent model. Subsequently, the data were fit with the raster covariates from the child models, with a binomial model using a spatially explicit mixed-effects generalised linear model via integrated nested Laplace approximation. Predictions were generated from this model by drawing 250 samples from the posterior distribution and taking the mean of these draws. The 95% UIs were generated by calculating the 2·5th and 97·5th percentiles of the drawn samples. Uncertainty for estimates are presented for piped and improved water and sanitation indicators in the appendix (pp 39–42). To ensure our predictions were aligned with national-level temporal trends, we fitted a generalised additive linear model to nationally representative data for each country. We calibrated the geospatial model to estimates from the national model by ensuring that, when aggregated to the national level, the geospatial estimates matched the corresponding estimates from the national model. Model fits were assessed via five-fold cross-validation and calculating out-of-sample root-mean squared errors, bias, and 95% coverage for each model (appendix pp 10–11). Analyses were done with R, version 3.5.0. Maps were produced with ArcGIS Desktop 10.6. Further details for model specification and methods can be found in the appendix (pp 9–11).

We measured access as the proportion of the population accessing the corresponding water and sanitation facility type in a given geographical area at a specific time. To assess progress over time, we calculated the mean annual change from 2000 to 2017.

For the **data visualisation tool** see https://vizhub.healthdata.org/lbd/wash

To assess the effect of changes in water and sanitation access on diarrhoeal disease mortality in children younger than 5 years, we used a comparative risk assessment framework to construct counterfactuals and assess child deaths averted due to increased access.[2] We used estimates of diarrhoeal mortality in children younger than 5 years available at the same spatial scales from the geospatial analysis described by Reiner and colleagues[36] for this counterfactual analysis; as such, only countries with data available from Reiner and colleagues were included. We combined these mortality estimates with risk ratios estimated in GBD 2017,[2] which associated different types of water and sanitation facilities with varied risks of diarrhoeal disease. To use the risk ratios for different categories of water access from GBD, we combined our estimates of water access with household water treatment prevalence data from GBD to create concordant categories of water facility exposures. With these data, we calculated population attributable fractions of child diarrhoeal deaths to unsafe water and sanitation.[2,26] We then used access estimates in 2000 to calculate a counterfactual population attributable fraction. Using these population attributable fractions in conjunction with the Reiner and colleagues estimates of child diarrhoeal disease mortality across units,[36] we calculated attributable under-5 deaths for water and sanitation in 2017, as well as the number of averted child deaths in 2017 due to changes in water and sanitation access since 2000. We propagated uncertainty by repeating the calculation for values from each of the 250 draws of the posterior from our model. This methodology is further outlined in the appendix (p 11).

Additionally, we estimated inequality using subnational variation across units and the Gini coefficient,[37] which summarises the distribution of each indicator across the population, with a value of zero representing perfect equality and a value of one representing maximum inequality (appendix pp 11–12).

Role of the funding source

The funder had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Access to all facility-type indicators for drinking water varied spatially and temporally. Across all LMICs assessed, access to piped water increased between 2000 and 2017 (from 40·0% [95% UI 39·4–40·7] to 50·3% [50·0–50·5] of the population), but this trend differed across regions (figure 2). Access to improved water overall increased from 82·6% (95% UI 82·3–82·8) in 2000 to 87·0% (86·8–87·1) in 2017 (figure 2; appendix p 32). Access levels for each unit are presented in the appendix and online through our data visualisation tool.

Although access to piped water was lowest in sub-Saharan Africa compared with other regions in 2017, notable areas of high access are apparent within sub-Saharan Africa (figure 2). Across sub-Saharan Africa, at least 80% of the population had access (henceforth referred to as high access) to piped water in 2017 in 5·9% (95% UI 5·7–6·2) of units, but 54·0% (53·5–54·8) of units had decreases in piped water access from 2000 to 2017, such as the Western Urban district of Sierra Leone (52·9% decrease [50·2–55·1]; figure 2). Units with high access to piped water facilities in sub-Saharan Africa mostly corresponded to large urban centres, such as Addis Ababa, Ethiopia (97·7% [95% UI 97·0–98·1]), and the Department of Guédiaway in Dakar, Senegal (92·9% [91·0–94·2]). However, in urban centres and other densely populated areas, a high absolute number of people continued to have no access even where unit-level access was high. For example, unit-level access to piped water was 90·5% (95% UI 85·2–95·3) in Casablanca, Morocco, yet 398 300 (198 500–618 500) people had no access. Large increases in piped water access also occurred from 2000 to 2017 for several African countries. In Niger, national-level piped water access increased from 23·5% (95% UI 22·7–24·4) to 47·6% (46·6–48·5), with a 1·3% mean annual percentage-point increase. In sub-Saharan Africa, 19·3% (95% UI 16·2–19·1) of units increased piped water access by more than 10 percentage points (figure 2). Access to improved water facilities overall was widespread in Africa, despite the relatively lower levels of piped water access: 56·8% (95% UI 56·3–57·3) of units had high access (>80%) to improved water in 2017 (appendix p 32).

In south Asia, piped water access was relatively low, with just 8·5% (95% UI 7·8–9·2) of units with high access to piped water in 2017 (figure 2). However, improved water access overall was relatively high in the region, increasing from 83·1% (95% UI 82·9–83·3) in 2000 to 92·5% (92·3–92·6) in 2017. Access to piped water was much higher in southeast Asia, east Asia, and Oceania in 2017, where 58·1% (95% UI 57·5–58·5) of units had high access. However, most of this piped water access was concentrated in China; when excluding China, access to piped water was just 3·2% (95% UI 2·8–3·7) in the region. Access to improved water remained relatively stable in southeast Asia, east Asia, and Oceania over the study period. Access was 91·2% (95% UI 90·6–91·7) in 2000 and 88·7% (88·3–89·1) in 2017. In southeast Asia, east Asia, and Oceania overall, access to improved water was high (>80%) in 77·0% (95% UI 76·1–77·8) of units in 2017, and the mean annual change in access was more than 2 percentage points in 7·1% (6·3–7·8) of units since 2000.

Access to piped water was relatively high in much of Latin America: 51·0% (95% UI 49·0–53·1) of units had high access to piped water in 2017 (figure 2). Improved water access increased in Latin America since 2000, from 89·6% (89·3–89·7) to 93·2% (93·1–93·3). Individual units also had large increases in access to improved water—eg, 96·4% (94·4–97·9) of units in Peru increased improved water access by more than 10 percentage points.

We sought to identify which units made transitions from no facility (ie, surface water or open defecation) in 2000 to improved facilities in 2017, compared with more gradual transitions (from no facility to unimproved facilities, or unimproved to improved facilities) over the study period. To do so, we compared the most common type of water and sanitation access in each unit (access level of more than 60% of the population; figure 3). Across all LMICs, 397 (95% UI 371–428) units in 2000 had 60% or more of their populations that relied on surface water. Of these, 176 (156–197) units had substantial upgrades—transitioning to 60% or more using improved facilities by 2017. In comparison, 780 (95% UI 741–825) units had 60% or more of people relying on surface water or 60% or more of people using unimproved facilities in 2000; of these, relatively incremental upgrades (either from surface water to unimproved facilities, or from unimproved to improved water facilities) occurred in 182 (95% UI 160–205) units. The full array of model outputs can be accessed online via our customised online visualisation tools.

For the **data visualisation tool** see https://vizhub.healthdata.org/lbd/wash

We used a comparative risk assessment framework to estimate the number of deaths in children younger than 5 years attributed to unsafe water and sanitation in 2017 and the number of child deaths averted due to changes in access. In 2017, 143 300 (95% UI 126 100–163 000) deaths in children younger than 5 years in sub-Saharan Africa were attributable to unsafe water, and 18 100 (15 700–21 200) child deaths were averted by increases in safe water access (figure 4). In southeast Asia, east Asia, and Oceania, 9470 (95% UI 8650–10 300) child deaths were attributable to unsafe water in 2017, whereas increases in safe water averted at least 1310 (1200–1440) child deaths in 2017.

Subnational disparities in access to improved drinking water and sanitation facilities, defined as the range of values from the unit with the highest level of access to the unit with the lowest level of access, are evident across LMICs (figure 5). For improved water, disparities decreased in 76·1% (95% UI 71·6–80·7) of LMICs from 2000 to 2017. El Salvador and Mexico had among the greatest reductions in disparity for improved water, although absolute and relative inequalities still persisted in 2017; the lowest access in Mexico was 56·7% (95% UI 29·8–77·1) less than the national mean in 2000 (3·0 times lower), and 20·8% (5·7–36·8) less than the mean (1·3 times lower) in 2017. Disparities in access to improved water changed in different ways across countries. In Ethiopia, the gap between the units with the lowest and highest access closed largely because the lowest level of access in 2000 drew closer to the highest level of access by 2017, increasing mean access to improved water nationally in 2017. By comparison, mean access to improved water was increased nationally in

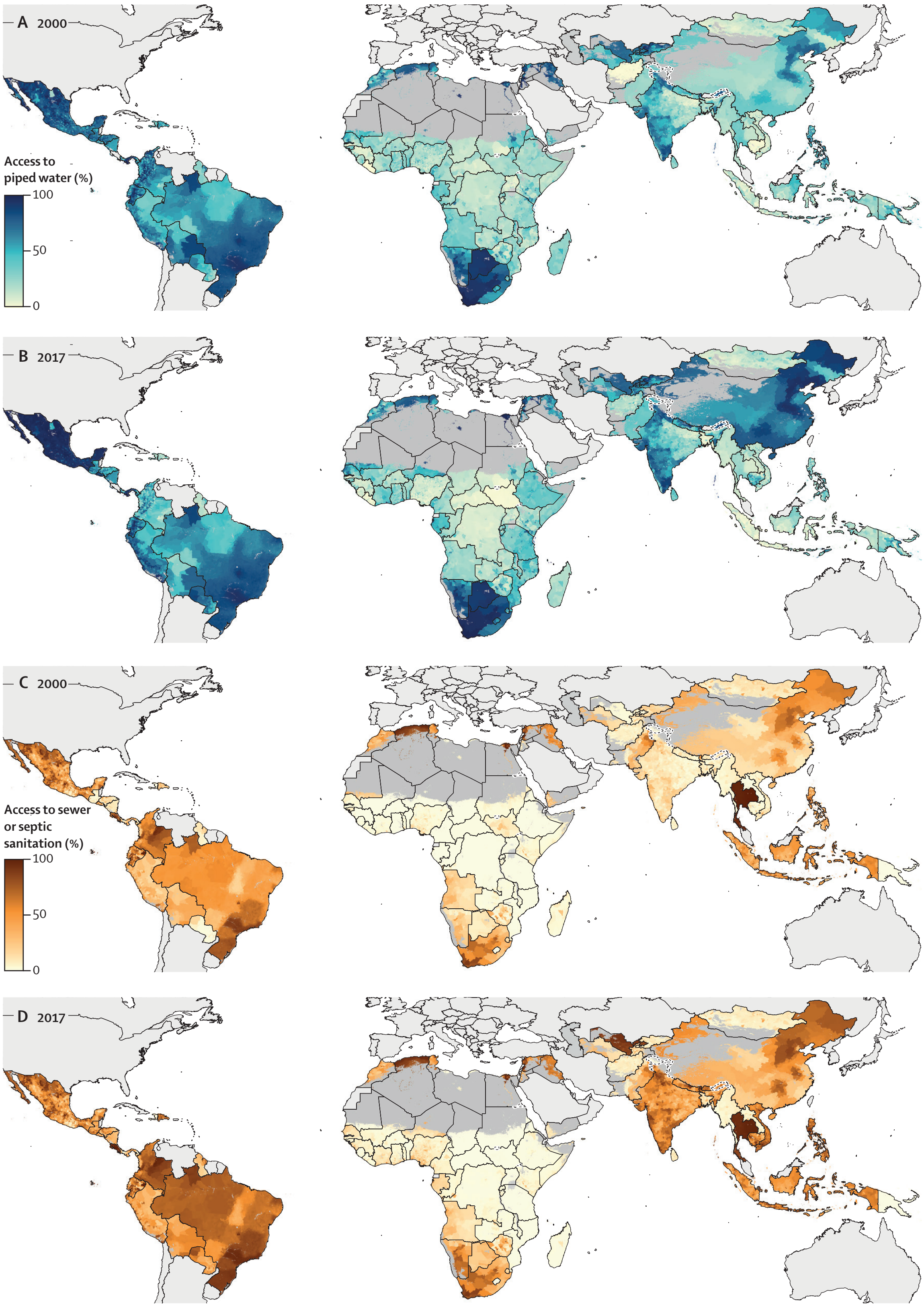

Figure 2: **Access to piped water and sewer or septic sanitation at the second-administrative-unit level, 2000 and 2017**
Access was modelled with use of model-based geostatistics for continuous continent-wide surfaces and aggregated to the second administrative level. The results for piped water are shown for years 2000 (A) and 2017 (B). The results for sewer or septic sanitation are also shown for 2000 (C) and 2017 (D). Maps reflect administrative boundaries, land cover, lakes, and population; dark grey-coloured grid cells were classified as barren or sparsely vegetated and had fewer than ten people per 1 × 1-km grid cell, or were not included in these analyses.[38–43] Interactive visualisation tools are available online.

For the **visualisation tools** see https://vizhub.healthdata.org/lbd/wash

Mozambique by 2017, but the lowest access level was similar in 2000 and 2017, while the highest level of access increased, widening the total range. Inequalities as determined with use of the Gini coefficient revealed additional trends. In 2000, 25 LMICs had Gini coefficients that exceeded 0·15 for improved water access, whereas in 2017, only nine remained higher than that level.

Access to sewer or septic sanitation across all LMICs increased from 28·7% (95% UI 28·5–29·0) in 2000 to 46·3% (46·1–46·5) in 2017, whereas access to improved sanitation overall increased from 60·0% (59·8–60·1) to 75·8% (75·7–75·9; figure 2, appendix p 36). Some regions saw large increases in access to sewer or septic sanitation since 2000, whereas access remained low across the study period in others.

Access to sewer or septic sanitation in sub-Saharan Africa was concentrated in similar areas to piped water, but just 1·0% (95% UI 1·0–1·0) of units had high access in the region, such as Bulawayo, Zimbabwe (96·5% access [95·8–97·1]; figure 2). In places with high unit-level access, many individuals can remain without access to sewer or septic sanitation. For instance, despite 88·6% (87·2–89·7) of the population of Harare, Zimbabwe having access, more than 253000 people did not have access in 2017.

In south Asia, there was high access to sewer or septic sanitation in 11·3% (95% UI 9·4–12·9) of units in 2017 (figure 2). Improved sanitation overall had high unit-level access in 69·0% (95% UI 67·6–70·4) of units in south Asia, increasing from a regional access level of 29·4% (29·1–29·6) in 2000 to 79·4% (79·2–79·7) in 2017. Access to sewer or septic sanitation was higher in southeast Asia, east Asia, and Oceania compared with south Asia in 2017; 42·0% (95% UI 40·8–43·1) of units in the region had high access. Substantial increases in sewer or septic sanitation access occurred over the study period, such as in Rapti District, Mid-Western Region, Nepal, (49·3% [95% UI 43·5–54·9] increase; mean annual change of 2·7 percentage points). Unit-level access to improved sanitation was high in 67·8% (95% UI 66·8–69·0) of units in southeast Asia, east Asia, and Oceania, increasing from 81·6% (81·2–82·0) to 85·9% (85·7–86·2) over the study period.

In Latin America, there was high access to sewer or septic sanitation in 32·8% (95% UI 31·7–33·8) of units in 2017 (figure 2). Latin America notably had an 11·8% increase in access to sewer or septic sanitation over the period (from 59·5% [59·3–59·8] to 71·3% [70·9–71·6]). Large increases occurred in sewer or septic sanitation from 2000, including in San Pedro Sula, Cortés, Honduras (increase of 35·9% [32·4–39·5], mean annual change of 2·0 percentage points). Access to improved sanitation overall was also high across the region, with more than half (54·5% [53·6–55·6]) of units in Latin America with high (>80%) access.

Of the 1830 (95% UI 1797–1863) units in which 60% or more of people practised open defecation in 2000, 686 (664–711) transitioned substantially to having access to improved facilities in 2017 (figure 3). By contrast, 580 (550–610) of the 5630 (5560–5690) units in which 60% or more of people practised open defecation or in which 60% or more of people used unimproved facilities in 2000 transitioned incrementally by 2017. Subnationally, many units in Ethiopia, such as Afder Zone, Somali, increased access to improved sanitation (11·6% [12·4–16·8] in 2000; 26·0% [22·8–29·0] in 2017) while substantially reducing open defecation (79·7% [77·0–82·1] in 2000; 43·3% [39·1–47·2] in 2017) over the period. Populations with high reliance on open defecation in 2017, were mostly concentrated in trans-border regions in southern Angola–northern Namibia and in west and central Africa.

According to our comparative risk assessment framework, in 2017, 182 300 (95% UI 159 900–208 200) under-5 child deaths in sub-Saharan Africa were attributed to unsafe sanitation, whereas increases in safe sanitation access averted at least 10100 (8970–11400) child deaths in the region (figure 4). In southeast Asia, east Asia, and Oceania, increases in safe sanitation averted at least 2750 (95% UI 2530–3040) child deaths, with 7810 (7050–8700) child deaths attributable to unsafe sanitation in 2017, compared with 1840 (1660–2070) averted child deaths and 4400 (4080–4690) child deaths attributable to unsafe sanitation in Latin America in 2017.

Subnational disparities in improved sanitation decreased in 53·9% (95% UI 50·6–59·6) of countries from 2000, and large decreases occurred in Vietnam and Cambodia, among other locations, although disparities were evident across LMICs in 2017 (figure 5). The lowest-access unit in Cambodia was 4·9 times less than the national mean in 2000, and just 1·4 times less than in 2017. Temporal trends in disparities varied in LMICs. In Namibia, mean access to improved sanitation increased overall from 2000 to 2017, but the lowest level of access remained relatively unchanged since 2000. Conversely, the highest level of access and the lowest level of access increased substantially in Cambodia over the study period. With use of the Gini coefficient, we found that many countries had consistent subnational inequality in improved sanitation, with Gini coefficients of more than 0·15 in 37 LMICS in 2000 and 30 LMICs in 2017. Notably, Chad, Libya, and Togo had Gini coefficients of more than 0·35 in 2017.

Discussion

Access to safe drinking water and sanitation facilities has improved globally between 2000, and 2017, but disparities in access varied across LMICs, presenting a barrier to achieving the SDG goal of universal access (100% access). Many units, such as in Cambodia for drinking water, had sizeable transitions, with the great majority of the population relying on the lowest quality of facility types in 2000 but accessing improved facilities by 2017. These units are exemplars that merit further study to identify

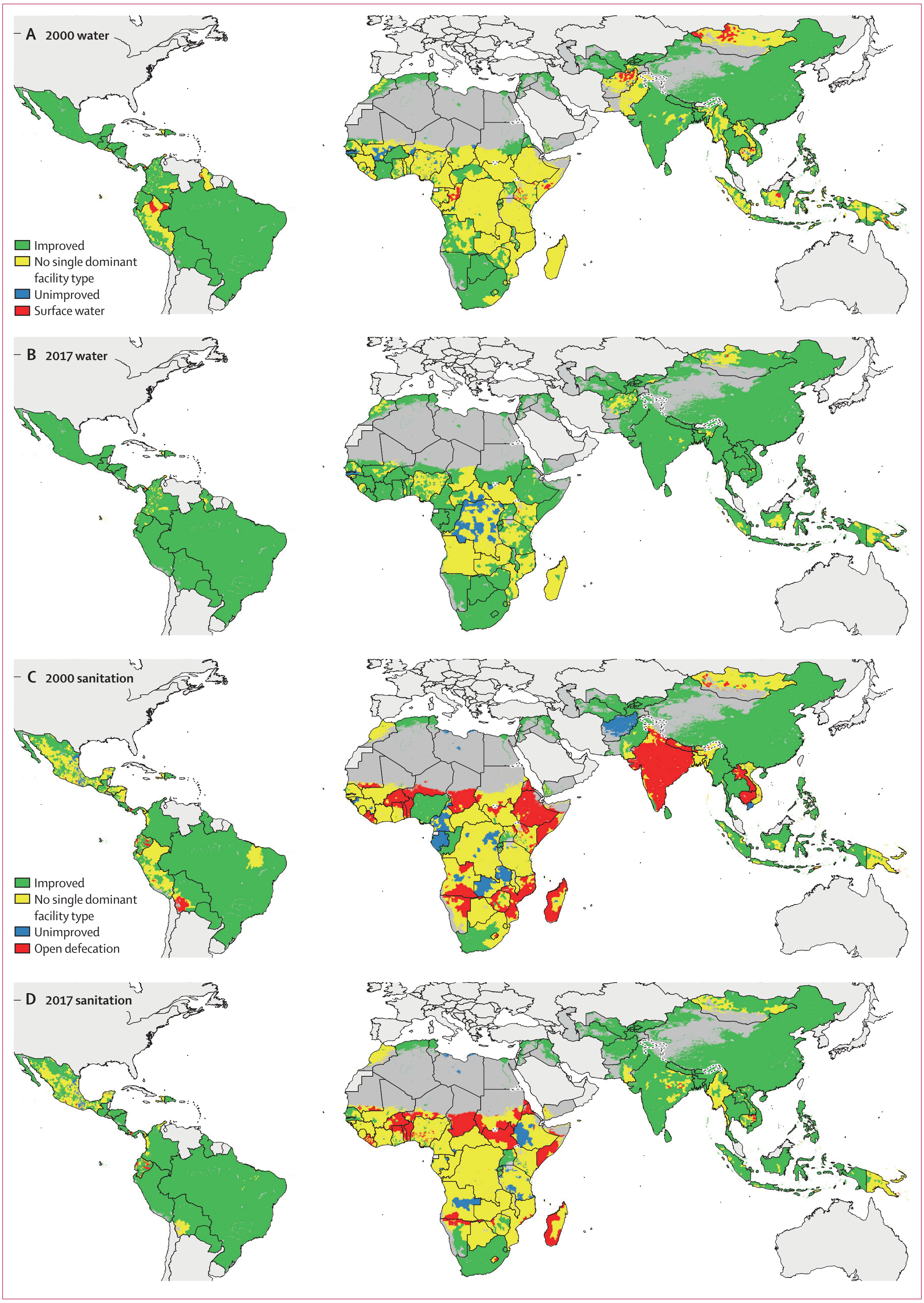

Figure 3: **Water and sanitation facility types used at the second-administrative-unit level, 2000 and 2017**
The co-distribution of improved, unimproved, and no facility access is shown for water for 2000 (A) and 2017 (B) and sanitation for 2000 (C), and 2017 (D). Green denotes second administrative-level units where most of the population (>60%) had access to improved facilities, blue denotes a more than 60% reliance on unimproved facilities, and red denotes more than 60% relying on surface water in A and B or practicing open defecation in C and D. Yellow indicates that there was no single dominant facility type used by more than 60% of the unit's population. Maps reflect administrative boundaries, land cover, lakes, and population; dark grey-coloured grid cells were classified as barren or sparsely vegetated and had fewer than ten people per 1 × 1-km grid cell, or were not included in these analyses.[38–43]

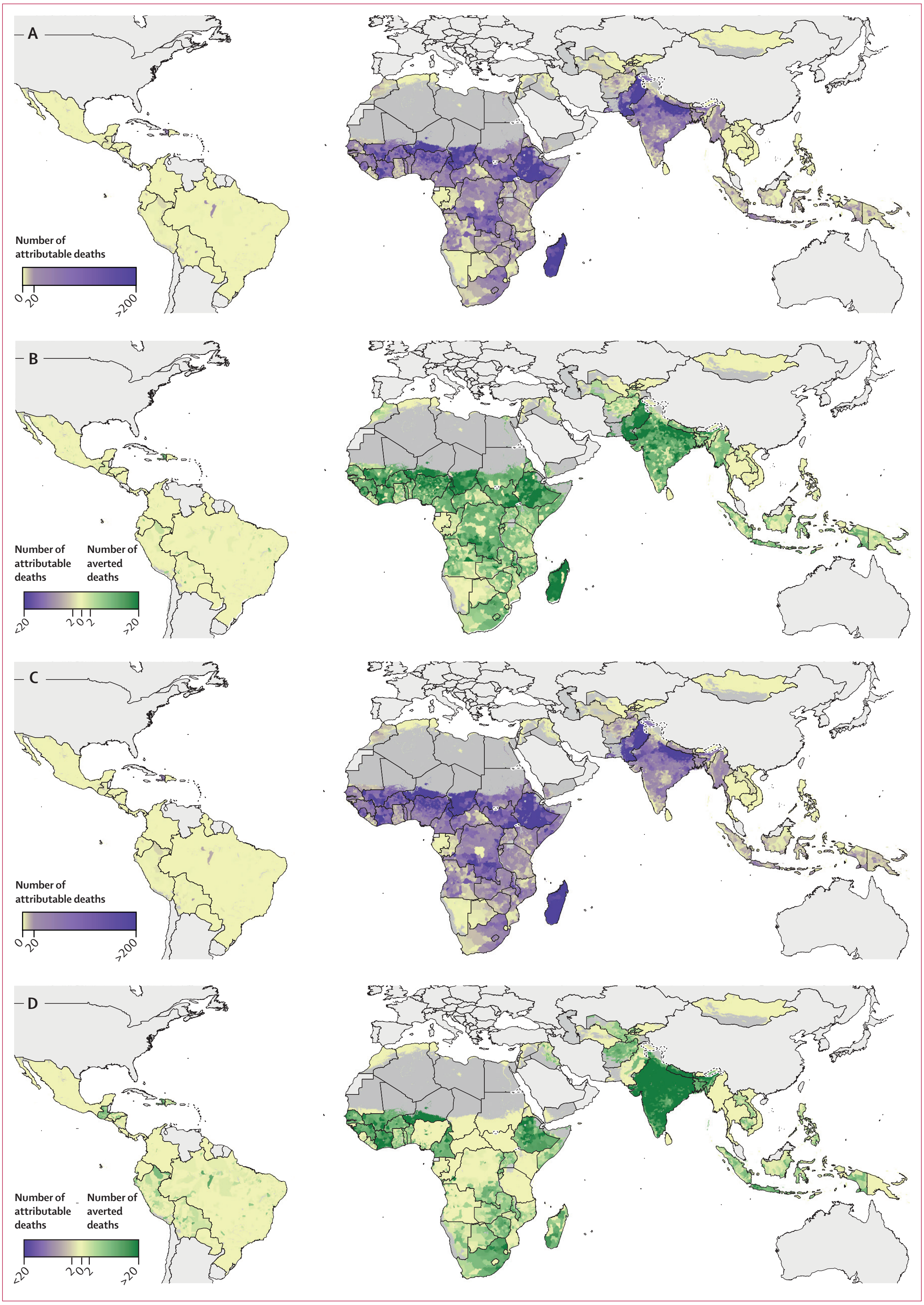

***Figure 4:* Effect of changes in access to water and sanitation in 2017 on child diarrhoeal deaths at the second-administrative-unit level**

Deaths are calculated under the counterfactual scenario in which access to safe water and sanitation remained at the values observed in the year 2000. The number of deaths attributed given access levels observed in 2017 is shown for water (A) and sanitation (C). The number of deaths averted (shown in green) or caused (shown in purple) in 2017 due to changes in access levels compared with 2000 is shown for water (B) and sanitation (D). Maps reflect administrative boundaries, land cover, lakes, and population; dark grey-coloured grid cells were classified as barren or sparsely vegetated and had fewer than ten people per 1 × 1-km grid cell, or were not included in these analyses.[38–43]

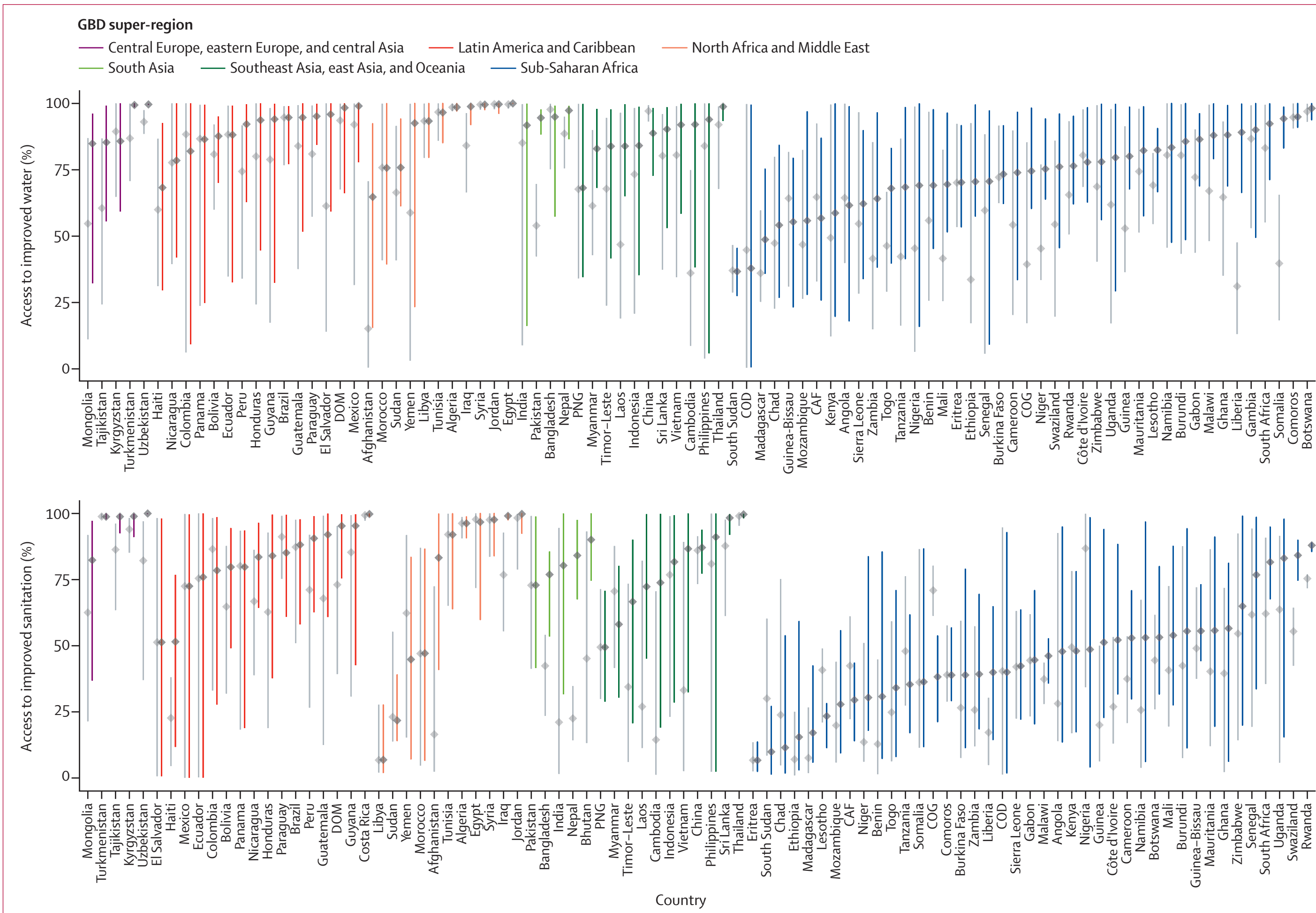

Figure 5: **Geographical inequality in access to improved water and sanitation**

Persistence of geographical inequality in access to improved facility types for water and sanitation and changes since 2000 are shown. Each bar's height plots the level of access to improved water and sanitation, from the lowest to the highest access second administrative-level unit in 2000 (grey) and 2017 (coloured by region). Mean access at the national level is shown as grey dots. Colours correspond to Global Burden of Disease regions. Countries not shown were excluded from the study due to limited data availability. CAF=Central African Republic. COD=Democratic Republic of Congo. COG=Republic of Congo. DOM=Dominican Republic. GNQ=Equatorial Guinea. PNG=Papua New Guinea.

drivers of success for replication elsewhere. In many countries, however, such progress was concurrent with increasing geographical inequality, as some units were effectively left behind. Our local-level estimates provide information to better target interventions to ensure progress towards greater access without increasing geographical inequality.

Estimates of access at the unit level support local monitoring of progress towards the SDG targets. Although our estimates of access to safe drinking water and sanitation facilities represent a best-case scenario of SDG attainment, in that they do not capture all the elements of safe management as defined by the JMP, even in the best-case scenario it is evident that many locations will need to scale up access to attain the goal of universal coverage. These results also show that estimates of access stratified by urban or rural status only or at the first administrative level are likely to mask further localised heterogeneity. By providing estimates at the second administrative level, in which programmatic decisions are often made, our results enable local decision makers to target resources and programmes with greater precision. Given that household-level water, sanitation, and hygiene interventions have had mixed results,[44–46] these estimates can support targeting interventions at the community level to maximise efficiency and serve areas most in need of access.

Although increases in access to improved water facilities overall were observed in sub-Saharan Africa, access to piped water remained low in 2017. Decreases in piped water access were particularly apparent in some regions of sub-Saharan Africa, where demographic changes might be outpacing infrastructure development. The bulk of interventions in sub-Saharan Africa have focused on increasing access to improved wells or springs, and the relatively high rates of access to other improved water facilities in LMICs in 2017 indicates that these interventions have largely been successful. Further investment in piped drinking water is needed to scale up and maintain access and to ensure consistent and quality access. Although initially costly, these efforts will ultimately improve economic productivity, supporting national development and stability.[47,48]

Our estimates revealed several units in which access to the safest facility types improved substantially. Exemplars in increasing piped water access include Svay Pao District, Battambang, Cambodia; Jantetelco Municipality, Morelos, Mexico; and Harari People's National Regional State, Ethiopia. Alongside economic growth nationally, the autonomous Phnom Penh Water Supply Authority has been credited with substantial expansion of Cambodia's urban piped water supply, whereas national and regional policy and government investment are likely to have played a role in Mexico and Ethiopia.[49–51] Further research on successful interventions in these locations could help other units to adapt similar strategies. The same is true for exemplars of increased sewer or septic sanitation, including Kampong Chhnang District, Cambodia, and Bagmati Zone, Central Development Region, Nepal, where potential drivers include governance guided by national and regional policies, infrastructure construction and management, and (in the case of Nepal) social movements.[52–55] Urbanisation generally leads to increased water and sanitation infrastructure, although informal settlements in urban areas are often excluded, presenting a challenge to achieving equity in access.[56] Although access to the safest facility types is lowest across sub-Saharan Africa, several units have high access in the region. These exemplars indicate that increasing access to piped systems in sub-Saharan Africa is entirely possible, despite demands on infrastructure and long-term maintenance. Here, we consider the safest facilities to be those with the lowest health risk, defined as the lowest associated risk-ratio for diarrhoeal disease. Considerations of cost-effectiveness and logistical needs will probably influence what technology is the most appropriate for any single community, and these decisions can be more effectively made at the local level.

In countries where access to safer facilities increased only in units with existing access to improved facilities—eg, transitioning from improved wells to piped—the population relying on the worst facility types was effectively left behind. Transitions to the safest facility type have the greatest potential to protect health compared with more moderate transitions.[11,57] Improved facilities might not prevent environmental contamination and disease transmission after long-term use or in poor environmental conditions.[58] Although piped water and sewer or septic sanitation have the greatest potential to prevent deaths from enteric diseases,[2] piped systems are also susceptible to contamination,[59] and water quality is not currently captured in our estimates. Despite having a smaller effect on health outcomes, transitions from surface water or open defecation to unimproved facilities, nonetheless represent important progress and potentially improved quality of life, including time saved for education and economic productivity.[14,15] Decision makers would benefit from detailed local information on the differences in increases by type of access to better target future interventions.

Achieving universal access in line with the SDG target is likely to require tailored interventions framed within a broader focus on reducing disparities. Countries such as Mozambique were able to increase mean access to improved water facilities, but although the highest level of access increased, the lowest level was relatively stable from 2000 to 2017, potentially reflecting improvements concentrated in urban centres with large populations where access was already higher. Targeted rural interventions might be needed to serve those with the lowest levels of access, for whom increases in access have not been as substantial. Ethiopia, for example, was able to increase the lowest levels of access to improved water facilities by 2017. In remote communities where a small number of people continue to have no access despite a high national access level, local-level investments in infrastructure are probably most suitable to address this disparity. Conversely, in Nigeria, where large numbers of people concentrated in single units do not have access to safe sanitation, more centralised solutions might best serve these dense urban populations. Examples such as improved water access in Cambodia, which saw pronounced increases in both the lowest access and highest access relative to 2000 levels, potentially present models for adoption elsewhere. Previous studies have identified poor, indigenous, and rural communities as the least likely to have access.[51,60] Although the disparity in access between urban and rural areas has long been recognised, our estimates underscore the ongoing need for investment in rural water and sanitation.

Our results identified several units in which changes in access to safe water averted relatively few child deaths, or decreased access to safe water led to increased child diarrhoeal mortality. This finding largely reflects decreases in piped water access in some units—potentially driven in part by conflict and instability,[61] particularly in areas such as in northeastern Nigeria—and suggests that what improvements in access did occur were not for the safest forms of facilities or that the improvements were not of a sufficient magnitude to have a major effect. In addition, our estimates do not capture other elements of safety, such as safe water storage and safe disposal of child faeces, which could drive reductions in diarrhoeal deaths.[4] Although the absolute number of deaths averted in a unit might not be large, the number of deaths attributable to unsafe water and sanitation in 2017 remains high, indicating that efforts to expand access would also reduce child mortality. Investments in increasing access to improved water and sanitation facilities are likely to have the greatest effect on reducing child deaths due to diarrhoea when coupled with other measures that protect children.[1,26] Other factors, such as treatment with oral rehydration solution, could have a combined effect with water and sanitation access on preventing child diarrhoeal deaths. Coverage of oral rehydration therapy over the study period has been mapped in a companion article by Wiens and colleagues.[62] More broadly, strengthening primary health-care systems and addressing social and economic determinants of health will also be imperative to successfully reduce disease and prevent child deaths. Our estimates can help by identifying areas susceptible to disease spread, aiding vaccine-targeting efforts, and assisting disease elimination campaigns in focusing on where they will be most successful. The relationship between access to water and sanitation and the spread of NTDs provides a particular opportunity to coordinate and improve disease prevention efforts across sectors.[10,63,64] Water, sanitation, and hygiene are also integral to the treatment of some NTDs, such as lymphatic filariasis and podoconiosis.[65,66] Our estimates facilitate targeting infrastructure investments toward communities with a high burden of NTDs, such as those identified through the Global Trachoma Mapping Project,[67] and low levels of access to drinking water and sanitation facilities.

The geostatistical nature of this analysis allows for explicit incorporation of geopositioned data, more effectively capturing local variation in access over space and time, compared with studies that use exclusively areal data.[13] Additionally, the use of a continuation-ratio modelling framework appropriately accounts for the ordinal relationships between indicators of water or sanitation facility type. This study also uses an extensive suite of covariates to leverage the complex relationships between water and sanitation access and environmental, social, and public health correlates at the local level. Our findings highlight the need to increase investment, assess existing interventions, scale up and expand successes, and improve monitoring of access to these facilities. Ultimately, these estimates, in combination with parallel work on oral rehydration therapy,[62] provide an actionable atlas to progress toward universal access, reduce child diarrhoeal mortality and the spread of disease, and improve wellbeing worldwide.

The data and methodology underlying these results have several limitations. First, SDG 1.4.1 aims to achieve universal access to basic services, and SDG 6 aims to achieve universal access to safely managed services; however, current data are insufficient to produce reliable estimates of these dimensions of access at the spatial and temporal scale presented here. Consequently, this analysis focused on access by facility type classification (figure 1), and our estimates provide a best-case scenario for the SDGs (all improved facilities are safely managed and provide basic services). Second, despite the fine spatial resolution of this study, these results might not fully represent intra-urban disparities in water and sanitation. Third, to incorporate the vast quantity of areal data in a geostatistical framework, areal data were transformed into geopositioned point data over the corresponding geographical area. This method could result in smoothed estimates in areas with predominantly areal data. Fourth, our data do not capture the impacts of conflicts or climate change-related weather events and disasters, and data for locations affected by these factors might not reflect current conditions. Fifth, survey data are subject to known biases and inaccuracies in reporting, and these issues coupled with data scarcity in some locations could affect the accuracy of our estimates. Sixth, our analysis of inequality is limited to variation in access and does not encompass social and economic factors affecting inequality in access. Seventh, uncertainty in existing population estimates affects the precision of our count estimates of access. Finally, although our model generates estimates of uncertainty considering the covariates as well as spatiotemporal trends, uncertainty is not explicitly incorporated from the survey design or the intermediate covariates generated from our stacking procedure (appendix p 9) due to computational limitations.

We plan to adopt the newly updated global indicators of water and sanitation access, including categories of basic and safely managed, by the WHO–UNICEF JMP. Although our study identified the best performing units and diverse modes of improvement across facilities, it was beyond our scope to identify the specific factors and interventions that contributed to these successes. Further research on potential shared characteristics across countries and units achieving high and equitable access could inform potential avenues for policy makers to adopt, particularly in light of the shifting focus from improved facility access to safely managed services. This analysis provides a comprehensive set of estimates across all facility types and locations; additional research with these methods to explore aspects presented here in greater detail would further enable prioritisation and targeting of water and sanitation interventions at the local level.

Despite substantial gains in some regions, accelerated progress will be necessary to achieve universal and equitable access to the safest forms of drinking water and sanitation facilities in line with SDG targets. Sub-Saharan Africa, in particular, would probably benefit from a precision public health approach to increasing access. This analysis improves on traditional national and subnational estimates, providing an analysis of both absolute and relative progress and identifies communities with low access as well as exemplars of improved access at the second administrative level. Our results indicate that vast geographical inequalities persist in both the proportion and number of people with access within countries, as well as in improvements of the quality of facilities over time. Local estimates can guide targeting of disease prevention efforts, particularly vaccines and interventions for nutrition and NTDs, to the communities with the lowest access. Ultimately, our estimates provide a resource for researchers, policy makers, and implementers to improve drinking water and sanitation access at local to national geographical scales, ensuring that all have access to this basic human right.

Local Burden of Disease WaSH Collaborators
Aniruddha Deshpande, Molly K Miller-Petrie, Paulina A Lindstedt, Mathew M Baumann, Kimberly B Johnson, Brigette F Blacker, Hedayat Abbastabar, Foad Abd-Allah, Ahmed Abdelalim, Ibrahim Abdollahpour, Kedir Hussein Abegaz, Ayenew Negesse Abejie, Lucas Guimarães Abreu, Michael R M Abrigo, Ahmed Abualhasan, Manfred Mario Kokou Accrombessi, Abdu A Adamu, Oladimeji M Adebayo, Isaac Akinkunmi Adedeji, Rufus Adesoji Adedoyin, Victor Adekanmbi, Olatunji O Adetokunboh, Tara Ballav Adhikari, Mohsen Afarideh, Marcela Agudelo-Botero, Mehdi Ahmadi, Keivan Ahmadi, Anwar E Ahmed, Muktar Beshir Ahmed, Temesgen Yihunie Akalu, Ali S Akanda, Fares Alahdab, Ziyad Al-Aly, Noore Alam, Samiah Alam, Genet Melak Alamene, Turki M Alanzi, James Albright, Ammar Albujeer, Jacqueline Elizabeth Alcalde-Rabanal, Animut Alebel, Zewdie Aderaw Alemu, Muhammad Ali, Mehran Alijanzadeh, Vahid Alipour, Syed Mohamed Aljunid, Ali Almasi, Amir Almasi-Hashiani, Hesham M Al-Mekhlafi, Khalid A Altirkawi, Nelson Alvis-Guzman, Nelson J Alvis-Zakzuk, Saeed Amini, Arianna Maever L Amit, Gianna Gayle Herrera Amul, Catalina Liliana Andrei, Mina Anjomshoa, Ansariadi Ansariadi, Carl Abelardo T Antonio, Benny Antony, Ernoiz Antriyandarti, Jalal Arabloo, Hany Mohamed Amin Aref, Olatunde Aremu, Bahram Armoon, Amit Arora, Krishna K Aryal, Afsaneh Arzani, Mehran Asadi-Aliabadi, Daniel Asmelash, Hagos Tasew Atalay, Seyyed Shamsadin Athari, Seyyede Masoume Athari, Sachin R Atre, Marcel Ausloos, Shally Awasthi, Nefsu Awoke, Beatriz Paulina Ayala Quintanilla, Getinet Ayano, Martin Amogre Ayanore, Yared Asmare Aynalem, Samad Azari, Andrew S Azman, Ebrahim Babaee, Alaa Badawi, Mojtaba Bagherzadeh, Shankar M Bakkannavar, Senthilkumar Balakrishnan, Maciej Banach, Joseph Adel Mattar Banoub, Aleksandra Barac, Miguel A Barboza, Till Winfried Bärnighausen, Sanjay Basu, Vo Dinh Bay, Mohsen Bayati, Neeraj Bedi, Mahya Beheshti, Meysam Behzadifar, Masoud Behzadifar, Diana Fernanda Bejarano Ramirez, Michelle L Bell, Derrick A Bennett, Habib Benzian, Dessalegn Ajema Berbada, Robert S Bernstein, Anusha Ganapati Bhat, Krittika Bhattacharyya, Soumyadeep Bhaumik, Zulfiqar A Bhutta, Ali Bijani, Boris Bikbov, Muhammad Shahdaat Bin Sayeed, Raaj Kishore Biswas, Somayeh Bohlouli, Soufiane Boufous, Oliver J Brady, Andrey Nikolaevich Briko, Nikolay Ivanovich Briko, Gabrielle B Britton, Alexandria Brown, Sharath Burugina Nagaraja, Zahid A Butt, Luis Alberto Cámera, Ismael R Campos-Nonato, Julio Cesar Campuzano Rincon, Jorge Cano, Josip Car, Rosario Cárdenas, Felix Carvalho, Carlos A Castañeda-Orjuela, Franz Castro, Ester Cerin, Binaya Chalise, Vijay Kumar Chattu, Ken Lee Chin, Devasahayam J Christopher, Dinh-Toi Chu, Natalie Maria Cormier, Vera Marisa Costa, Elizabeth A Cromwell, Abel Fekadu Dadi, Tukur Dahiru, Saad M A Dahlawi, Rakhi Dandona, Lalit Dandona, Anh Kim Dang, Farah Daoud, Aso Mohammad Darwesh, Amira Hamed Darwish, Ahmad Daryani, Jai K Das, Rajat Das Gupta, Aditya Prasad Dash, Claudio Alberto Dávila-Cervantes, Nicole Davis Weaver, Fernando Pio De la Hoz, Jan-Walter De Neve, Dereje Bayissa Demissie, Gebre Teklemariam Demoz, Edgar Denova-Gutiérrez, Kebede Deribe, Assefa Desalew, Samath Dhamminda Dharmaratne, Preeti Dhillon, Meghnath Dhimal, Govinda Prasad Dhungana, Daniel Diaz, Isaac Oluwafemi Dipeolu, Hoa Thi Do, Christiane Dolecek, Kerrie E Doyle, Eleonora Dubljanin, Andre Rodrigues Duraes, Hisham Atan Edinur, Andem Effiong, Aziz Eftekhari, Nevine El Nahas, Maysaa El Sayed Zaki, Maha El Tantawi, Hala Rashad Elhabashy, Shaimaa I El-Jaafary, Ziad El-Khatib, Hajer Elkout, Aisha Elsharkawy, Shymaa Enany, Daniel Adane Endalew, Babak Eshrati, Sharareh Eskandarieh, Arash Etemadi, Oluchi Ezekannagha, Emerito Jose A Faraon, Mohammad Fareed, Andre Faro, Farshad Farzadfar, Alebachew Fasil, Mehdi Fazlzadeh, Valery L Feigin, Wubalem Fekadu, Netsanet Fentahun, Seyed-Mohammad Fereshtehnejad, Eduarda Fernandes, Irina Filip, Florian Fischer, Carsten Flohr, Nataliya A Foigt, Morenike Oluwatoyin Folayan, Masoud Foroutan, Richard Charles Franklin, Joseph Jon Frostad, Takeshi Fukumoto, Mohamed M Gad, Gregory M Garcia, Augustine Mwangi Gatotoh, Reta Tsegaye Gayesa, Ketema Bizuwork Gebremedhin, Yilma Chisha Dea Geramo, Hailay Abrha Gesesew, Kebede Embaye Gezae, Ahmad Ghashghaee, Farzaneh Ghazi Sherbaf, Tiffany K Gill, Paramjit Singh Gill, Themba G Ginindza, Alem Girmay, Zemichael Gizaw, Amador Goodridge, Sameer Vali Gopalani, Alessandra C Goulart, Bárbara Niegia Garcia Goulart, Ayman Grada, Manfred S Green, Mohammed Ibrahim Mohialdeen Gubari, Harish Chander Gugnani, Davide Guido, Rafael Alves Guimarães, Yuming Guo, Rahul Gupta, Rajeev Gupta, Giang Hai Ha, Juanita A Haagsma, Nima Hafezi-Nejad, Dessalegn H Haile, Michael Tamene Haile, Brian J Hall, Samer Hamidi, Demelash Woldeyohannes Handiso, Hamidreza Haririan, Ninuk Hariyani, Ahmed I Hasaballah, Md Mehedi Hasan, Amir Hasanzadeh, Hamid Yimam Hassen, Desta Haftu Hayelom, Mohamed I Hegazy, Behzad Heibati, Behnam Heidari, Delia Hendrie, Andualem Henok, Claudiu Herteliu, Fatemeh Heydarpour, Hagos Degefa de Hidru, Thomas R Hird, Chi Linh Hoang, Gillian I Hollerich, Praveen Hoogar, Naznin Hossain, Mehdi Hosseinzadeh, Mowafa Househ, Guoqing Hu, Ayesha Humayun, Syed Ather Hussain, Mamusha Aman A Hussen, Segun Emmanuel Ibitoye, Olayinka Stephen Ilesanmi, Milena D Ilic, Mohammad Hasan Imani-Nasab, Usman Iqbal, Seyed Sina Naghibi Irvani, Sheikh Mohammed Shariful Islam, Rebecca Q Ivers, Chinwe Juliana Iwu, Nader Jahanmehr, Mihajlo Jakovljevic, Amir Jalali, Achala Upendra Jayatilleke, Ensiyeh Jenabi, Ravi Prakash Jha, Vivekanand Jha, John S Ji, Jost B Jonas, Jacek Jerzy Jozwiak, Ali Kabir, Zubair Kabir, Tanuj Kanchan, André Karch, Surendra Karki, Amir Kasaeian, Gebremicheal Gebreslassie Kasahun, Habtamu Kebebe Kasaye, Getachew Mullu Kassa, Gebrehiwot G Kassa, Gbenga A Kayode, Mihiretu M Kebede, Peter Njenga Keiyoro, Daniel Bekele Ketema, Yousef Saleh Khader, Morteza Abdullatif Khafaie, Nauman Khalid, Rovshan Khalilov, Ejaz Ahmad Khan, Junaid Khan, Md Nuruzzaman Nuruzzaman Khan, Khaled Khatab, Mona M Khater, Amir M Khater, Maryam Khayamzadeh, Mohammad Khazaei, Mohammad Hossein Khosravi, Jagdish Khubchandani, Ali Kiadaliri, Yun Jin Kim, Ruth W Kimokoti, Sezer Kisa, Adnan Kisa, Sonali Kochhar, Tufa Kolola, Hamidreza Komaki, Soewarta Kosen, Parvaiz A Koul, Ai Koyanagi, Kewal Krishan, Barthelemy Kuate Defo, Nuworza Kugbey, Pushpendra Kumar, G Anil Kumar, Manasi Kumar, Dian Kusuma, Carlo La Vecchia, Ben Lacey, Aparna Lal, Dharmesh Kumar Lal, Hilton Lam, Faris Hasan Lami, Van Charles Lansingh, Savita Lasrado, Georgy Lebedev, Paul H Lee, Kate E LeGrand, Mostafa Leili, Tsegaye Lolaso Lenjebo, Cheru Tesema Leshargie, Aubrey J Levine, Sonia Lewycka, Shanshan Li, Shai Linn, Shiwei Liu, Jaifred Christian F Lopez, Platon D Lopukhov, Muhammed Magdy Abd El Razek, D R Mahadeshwara Prasad, Phetole Walter Mahasha, Narayan B Mahotra, Azeem Majeed, Reza Malekzadeh, Deborah Carvalho Malta, Abdullah A Mamun, Navid Manafi, Mohammad Ali Mansournia, Chabila Christopher Mapoma, Gabriel Martinez, Santi Martini, Francisco Rogerlândio Martins-Melo, Manu Raj Mathur, Benjamin K Mayala, Mohsen Mazidi, Colm McAlinden, Birhanu Geta Meharie, Man Mohan Mehndiratta, Entezar Mehrabi Nasab, Kala M Mehta, Teferi Mekonnen, Tefera Chane Mekonnen, Gebrekiros Gebremichael Meles, Hagazi Gebre Meles, Peter T N Memiah, Ziad A Memish, Walter Mendoza, Ritesh G Menezes, Seid Tiku Mereta, Tuomo J Meretoja, Tomislav Mestrovic, Workua Mekonnen Metekiya, Bartosz Miazgowski, Ted R Miller, GK Mini, Erkin M Mirrakhimov, Babak Moazen, Bahram Mohajer, Yousef Mohammad, Dara K Mohammad, Naser Mohammad Gholi Mezerji, Roghayeh Mohammadibakhsh, Shafiu Mohammed, Jemal Abdu Mohammed, Hassen Mohammed, Farnam Mohebi, Ali H Mokdad, Yoshan Moodley, Ghobad Moradi, Masoud Moradi, Mohammad Moradi-Joo, Paula Moraga, Linda Morales, Abbas Mosapour,

Jonathan F Mosser, Simin Mouodi, Seyyed Meysam Mousavi, Miliva Mozaffor, Sandra B Munro, Moses K Muriithi, Christopher J L Murray, Kamarul Imran Musa, Ghulam Mustafa, Saravanan Muthupandian, Mehdi Naderi, Ahamarshan Jayaraman Nagarajan, Mohsen Naghavi, Gurudatta Naik, Vinay Nangia, Bruno Ramos Nascimento, Javad Nazari, Duduzile Edith Ndwandwe, Ionut Negoi, Henok Biresaw Netsere, Josephine W Ngunjiri, Cuong Tat Nguyen, Huong Lan Thi Nguyen, QuynhAnh P Nguyen, Solomon Gedlu Nigatu, Dina Nur Anggraini Ningrum, Chukwudi A Nnaji, Marzieh Nojomi, Ole F Norheim, Jean Jacques Noubiap, Bogdan Oancea, Felix Akpojene Ogbo, In-Hwan Oh, Andrew T Olagunju, Bolajoko Olubukunola Olusanya, Jacob Olusegun Olusanya, Obinna E Onwujekwe, Doris V Ortega-Altamirano, Osayomwanbo Osarenotor, Frank B Osei, Mayowa O Owolabi, Mahesh P A, Jagadish Rao Padubidri, Smita Pakhale, Adrian Pana, Eun-Kee Park, Sangram Kishor Patel, Ashish Pathak, Ajay Patle, Kebreab Paulos, Veincent Christian Filipino Pepito, Norberto Perico, Aslam Pervaiz, Julia Moreira Pescarini, Konrad Pesudovs, Hai Quang Pham, David M Pigott, Thomas Pilgrim, Meghdad Pirsaheb, Mario Poljak, Ian Pollock, Maarten J Postma, Farshad Pourmalek, Akram Pourshams, Sergio I Prada, Liliana Preotescu, Hedley Quintana, Navid Rabiee, Mohammad Rabiee, Amir Radfar, Alireza Rafiei, Fakher Rahim, Siavash Rahimi, Vafa Rahimi-Movaghar, Mohammad Hifz Ur Rahman, Muhammad Aziz Rahman, Fatemeh Rajati, Chhabi Lal Ranabhat, Puja C Rao, Davide Rasella, Goura Kishor Rath, Salman Rawaf, Lal Rawal, Wasiq Faraz Rawasia, Giuseppe Remuzzi, Vishnu Renjith, Andre M N Renzaho, Serge Resnikoff, Seyed Mohammad Riahi, Ana Isabel Ribeiro, Jennifer Rickard, Leonardo Roever, Luca Ronfani, Enrico Rubagotti, Salvatore Rubino, Anas M Saad, Siamak Sabour, Ehsan Sadeghi, Sahar Saeedi Moghaddam, Yahya Safari, Rajesh Sagar, Mohammad Ali Sahraian, S Mohammad Sajadi, Mohammad Reza Salahshoor, Nasir Salam, Ahsan Saleem, Marwa Rashad Salem, Hosni Salem, Yahya Salimi, Hamideh Salimzadeh, Abdallah M Samy, Juan Sanabria, Itamar S Santos, Milena M Santric-Milicevic, Bruno Piassi Sao Jose, Sivan Yegnanarayana Iyer Saraswathy, Nizal Sarrafzadegan, Benn Sartorius, Brijesh Sathian, Thirunavukkarasu Sathish, Maheswar Satpathy, Monika Sawhney, Mehdi Sayyah, Alyssa N Sbarra, Lauren E Schaeffer, David C Schwebel, Anbissa Muleta Senbeta, Subramanian Senthilkumaran, Sadaf G Sepanlou, Edson Serván-Mori, Azadeh Shafieesabet, Amira A Shaheen, Izza Shahid, Masood Ali Shaikh, Ali S Shalash, Mehran Shams-Beyranvand, MohammadBagher Shamsi, Morteza Shamsizadeh, Mohammed Shannawaz, Kiomars Sharafi, Rajesh Sharma, Aziz Sheikh, B Suresh Kumar Shetty, Wondimeneh Shibabaw Shiferaw, Mika Shigematsu, Jae Il Shin, Rahman Shiri, Reza Shirkoohi, K M Shivakumar, Si Si, Soraya Siabani, Tariq Jamal Siddiqi, Diego Augusto Santos Silva, Balbir Bagicha Singh, Ambrish Singh, Virendra Singh, Narinder Pal Singh, Jasvinder A Singh, Dhirendra Narain Sinha, Malede Mequanent Sisay, Eirini Skiadaresi, David L Smith, Adauto Martins Soares Filho, Mohammad Reza Sobhiyeh, Anton Sokhan, Joan B Soriano, Muluken Bekele Sorrie, Ireneous N Soyiri, Emma Elizabeth Spurlock, Chandrashekhar T Sreeramareddy, Agus Sudaryanto, Mu'awiyyah Babale Sufiyan, Hafiz Ansar Rasul Suleria, Bryan L Sykes, Rafael Tabarés-Seisdedos, Takahiro Tabuchi, Degena Bahrey Tadesse, Ingan Ukur Tarigan, Bineyam Taye, Yonatal Mesfin Tefera, Arash Tehrani-Banihashemi, Shishay Wahdey Tekelemedhin, Merhawi Gebremedhin Tekle, Mohamad-Hani Temsah, Fisaha Haile Tesfay, Berhe Etsay Tesfay, Zemenu Tadesse Tessema, Kavumpurathu Raman Thankappan, Akhil Soman ThekkePurakkal, Nihal Thomas, Robert L Thompson, Alan J Thomson, Roman Topor-Madry, Marcos Roberto Tovani-Palone, Eugenio Traini, Bach Xuan Tran, Khanh Bao Tran, Irfan Ullah, Bhaskaran Unnikrishnan, Muhammad Shariq Usman, Olalekan A Uthman, Benjamin S Chudi Uzochukwu, Pascual R Valdez, Santosh Varughese, Yousef Veisani, Francesco S Violante, Sebastian Vollmer, Feleke Gebremeskel W/hawariat, Yasir Waheed, Mitchell Taylor Wallin, Yuan-Pang Wang, Yafeng Wang, Kinley Wangdi, Daniel J Weiss, Girmay Teklay Weldesamuel, Adhena Ayaliew Werkneh, Ronny Westerman, Taweewat Wiangkham, Kirsten E Wiens, Tissa Wijeratne, Charles Shey Wiysonge, Haileab Fekadu Wolde, Dawit Zewdu Wondafrash, Tewodros Eshete Wonde, Getasew Taddesse Worku, Ali Yadollahpour, Seyed Hossein Yahyazadeh Jabbari, Tomohide Yamada, Mehdi Yaseri, Hiroshi Yatsuya, Alex Yeshaneh, Mekdes Tigistu Yilma, Paul Yip, Engida Yisma, Naohiro Yonemoto, Mustafa Z Younis, Hebat-Allah Salah A Yousof, Chuanhua Yu, Hasan Yusefzadeh, Siddhesh Zadey, Telma Zahirian Moghadam, Zoubida Zaidi, Sojib Bin Zaman, Mohammad Zamani, Hamed Zandian, Heather J Zar, Taddese Alemu Zerfu, Yunquan Zhang, Arash Ziapour, Sanjay Zodpey, Yves Miel H Zuniga, Simon I Hay*, Robert C Reiner Jr*.

*Joint senior authors.

Affiliations

Institute for Health Metrics and Evaluation (A Deshpande MPH, M K Miller-Petrie MSc, P A Lindstedt MPH, M M Baumann BS, K B Johnson MA, B F Blacker MPH, J Albright BS, A Brown MA, N M Cormier MPSA, E A Cromwell PhD, Prof R Dandona PhD, Prof L Dandona MD, F Daoud BS, N Davis Weaver MPH, Prof S D Dharmaratne MD, Prof V L Feigin PhD, J J Frostad MPH, G M Garcia BS, G I Hollerich BA, K E LeGrand MPH, A J Levine MSPH, B K Mayala PhD, Prof A H Mokdad PhD, J F Mosser MD, S B Munro PhD, Prof C J L Murray PhD, Prof M Naghavi MD, Q P Nguyen BS, D M Pigott PhD, I Pollock MLS, P C Rao MPH, A N Sbarra MPH, L E Schaeffer MS, Prof D L Smith PhD, E E Spurlock BA, R L Thompson PhD, K E Wiens PhD, Prof S I Hay FMedSci, R C Reiner Jr. PhD), Department of Health Metrics Sciences, School of Medicine (E A Cromwell, Prof R Dandona, Prof S D Dharmaratne, Prof A H Mokdad, Prof C J L Murray, Prof M Naghavi, D M Pigott, Prof B Sartorius PhD, Prof D L Smith, Prof S I Hay, R C Reiner Jr.), Department of Global Health (S Kochhar MD), University of Washington, Seattle, WA, United States; Advanced Diagnostic and Interventional Radiology Research Center (H Abbastabar PhD), Endocrinology and Metabolism Research Center (M Afarideh MD, B Heidari MD), Multiple Sclerosis Research Center (S Eskandarieh PhD, Prof M Sahraian MD), Non-communicable Diseases Research Center (Prof F Farzadfar DSc, B Mohajer MD, F Mohebi MD, S Saeedi Moghaddam MSc), Department of Environmental Health Engineering (M Fazlzadeh PhD), School of Medicine (N Hafezi-Nejad MD), Department of Microbiology (A Hasanzadeh PhD), Hematology, Oncology and Stem Cell Transplantation Research Center (A Kasaeian PhD), Digestive Diseases Research Institute (Prof R Malekzadeh MD, Prof A Pourshams MD, H Salimzadeh PhD, S G Sepanlou MD), Department of Epidemiology and Biostatistics (M Mansournia PhD, M Yaseri PhD), Tehran Heart Center (E Mehrabi Nasab MD), National Institute of Health Research (NIHR) (F Mohebi), Department of Health Policy, Management, and Economics (S Mousavi PhD), Metabolomics and Genomics Research Center (F Rahim PhD), Sina Trauma and Surgery Research Center (Prof V Rahimi-Movaghar MD), Cancer Research Institute (R Shirkoohi PhD), Cancer Biology Research Center (R Shirkoohi), Tehran University of Medical Sciences, Tehran, Iran; Department of Neurology (Prof F Abd-Allah MD, Prof A Abdelalim MD, A Abualhasan MD, S I El-Jaafary MD, M I Hegazy PhD), Neurophysiology Department (Prof H R Elhabashy MD), Endemic Medicine and Hepatogastroentrology Department (A Elsharkawy MD), Department of Medical Parasitology (M M Khater MD, H S A Yousof MD), National Hepatology and Tropical Medicine Research Institute (A M Khater MD), Urology Department (Prof H Salem MD), Cairo University, Cairo, Egypt; Neuroscience Research Center (I Abdollahpour PhD), Isfahan Cardiovascular Research Institute (Prof N Sarrafzadegan MD), Isfahan University of Medical Sciences, Isfahan, Iran; Department of Biostatistics (K H Abegaz MSc), Near East University, Nicosia, Cyprus; Department of Biostatistics and Health Informatics (K H Abegaz), Department of Public Health (G Alamene MPH), Madda Walabu University, Bale Robe, Ethiopia; Department of Nursing (A Alebel MSc, D H Haile MSc), Department of Public Health (Z A Alemu PhD, D B Ketema MPH, T E Wonde MPH), College of Health Sciences (G M Kassa MSc), Debre Markos University, Debre Markos, Ethiopia (A N Abejie MPH); Department of Pediatric

Dentistry (Prof L G Abreu PhD), Department of Maternal and Child Nursing and Public Health (Prof D C Malta PhD), Department of Clinical Medicine (Prof B R Nascimento PhD), Clinical Hospital (Prof B R Nascimento), Department of Infectious Diseases and Tropical Medicine (B P Sao Jose PhD), Federal University of Minas Gerais, Belo Horizonte, Brazil; Department of Research (M R M Abrigo PhD), Philippine Institute for Development Studies, Quezon City, Philippines; Department of Disease Control (M M K Accrombessi PhD, J Cano PhD), Department of Infectious Disease Epidemiology (O J Brady PhD), Faculty of Infectious and Tropical Diseases (Prof B Sartorius), London School of Hygiene & Tropical Medicine, London, United Kingdom; Clinical Research and Operations (M M K Accrombessi), Foundation for Scientific Research (FORS), Cotonou, Benin; Department of Global Health (A A Adamu PhD, O O Adetokunboh PhD, C J Iwu PhD), Stellenbosch University, Cape Town, South Africa; Cochrane South Africa (A A Adamu, D E Ndwandwe PhD), Grants, Innovation and Product Development Unit (P W Mahasha PhD), South African Medical Research Council, Cape Town, South Africa (C J Iwu, C A Nnaji MPH, Prof C S Wiysonge MD); College of Medicine (O M Adebayo MD), Department of Community Medicine (O S Ilesanmi PhD), Department of Medicine (Prof M O Owolabi DrM), University College Hospital, Ibadan, Ibadan, Nigeria; Department of Sociology (I A Adedeji PhD), Olabisi Onabanjo University, Ago-Iwoye, Nigeria; Department of Medical Rehabilitation (Prof R A Adedoyin PhD), Department of Child Dental Health (Prof M O Folayan FWACS), Obafemi Awolowo University, Ile-Ife, Nigeria; Population Health Sciences (V Adekanmbi PhD), King's College London, London, England; Centre of Excellence for Epidemiological Modelling and Analysis (O O Adetokunboh), Stellenbosch University, Stellenbosch, South Africa; Department of Public Health (T Adhikari MPH), Aarhus University, Aarhus, Denmark; Nepal Health Frontiers (T Adhikari), University of Southern Denmark, Kathmandu, Nepal; Department of Dermatology (M Afarideh), Mayo Clinic, Rochester, MN, United States; Center for Policy, Population & Health Research (Prof M Agudelo-Botero PhD), Center of Complexity Sciences (Prof D Diaz PhD), National Autonomous University of Mexico, Mexico City, Mexico; Environmental Technologies Research Center (M Ahmadi PhD), Environmental Health Engineering (M Ahmadi), Social Determinants of Health Research Center (M A Khafaie PhD), Thalassemia and Hemoglobinopathy Research Center (F Rahim), Education Development Center (M Sayyah MD), Medical Physics Department (A Yadollahpour PhD), Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran; Lincoln Medical School (K Ahmadi PhD), Universities of Nottingham & Lincoln, Lincoln, United Kingdom; Economics and Rural Development Department (A E Ahmed PhD), University of Gezira, Wad Madani, Sudan; Department of Epidemiology (M B Ahmed MPH), Department of Health, Behavior and Society (M A A Hussen MPH), Department of Environmental Health Sciences and Technology (S Mereta PhD), Jimma University, Jimma, Ethiopia; Australian Center for Precision Health (M B Ahmed), University of South Australia, Adelaide, SA, Australia; Department of Epidemiology and Biostatistics (T Y Akalu MPH, S G Nigatu MPH, M M Sisay MPH, Z T Tessema MSc, H F Wolde MPH), Department of Clinical Chemistry (D Asmelash MSc, A F Fasil MSc), Institute of Public Health (A F Dadi MPH, Z Gizaw MPH), School of Nursing (H B Netsere MS), University of Gondar, Gondar, Ethiopia; Department of Civil and Environmental Engineering (A S Akanda PhD), University of Rhode Island, Kingston, RI, United States; Mayo Evidence-based Practice Center (F Alahdab MSc), Mayo Clinic Foundation for Medical Education and Research, Rochester, MN, United States; John T. Milliken Department of Internal Medicine (Z Al-Aly MD), Washington University in St. Louis, St. Louis, MO, United States; Clinical Epidemiology Center (Z Al-Aly), Department of Veterans Affairs, St Louis, MO, United States; Prevention Division (N Alam MPH), Queensland Health, Brisbane, QLD, Australia; Centre for Environment and Population Health (N Alam), Griffith University, Nathan, QLD, Australia; Community Health and Epidemiology (S Alam MSc), Dalhousie University, Halifax, NS, Canada; Health Information Management and Technology Department (T M Alanzi PhD), Environmental Health Department (S M A Dahlawi PhD), Forensic Medicine Division (Prof R G Menezes MD), Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia; Nab'a Al-Hayat Foundation for Medical Sciences and Health Care, Najaf, Iraq (A Albujeer DDS); Center for Health System Research (J E Alcalde-Rabanal PhD, E Serván-Mori PhD), Health and Nutrition Research Center (I R Campos-Nonato PhD), Center for Nutrition and Health Research (E Denova-Gutiérrez DSc), Center for Population Health Research (L Morales MSc), Health Systems Research Center (D V Ortega-Altamirano DrPH), National Institute of Public Health, Cuernavaca, Mexico (J Campuzano Rincon PhD); School of Public Health (A Alebel), School of Health (S Siabani PhD), University of Technology Sydney, Sydney, NSW, Australia; Department of Biotechnology (M Ali PhD), Quaid-i-Azam University, Islamabad, Pakistan; Social Determinants of Health Research Center (M Alijanzadeh PhD), Qazvin University of Medical Sciences, Qazvin, Iran; Health Management and Economics Research Center (V Alipour PhD, J Arabloo PhD, S Azari PhD, A Ghashghaee BSc), Health Economics Department (V Alipour), Preventive Medicine and Public Health Research Center (M Asadi-Aliabadi MSc, E Babaee PhD, B Eshrati PhD, Prof M Nojomi MD, A Tehrani-Banihashemi PhD), Student Research Committee (A Ghashghaee), Minimally Invasive Surgery Research Center (A Kabir MD), Pars Advanced and Minimally Invasive Medical Manners Research Center (A Kasaeian), Department of Neurosurgery (M Khosravi MD), School of Medicine (N Manafi MD), Department of Community and Family Medicine (Prof M Nojomi, A Tehrani-Banihashemi), Iran University of Medical Sciences, Tehran, Iran; Department of Health Policy and Management (Prof S M Aljunid PhD), Kuwait University, Safat, Kuwait; International Centre for Casemix and Clinical Coding (Prof S M Aljunid), National University of Malaysia, Bandar Tun Razak, Malaysia; Department of Environmental Health Engineering (Prof A Almasi PhD), Medical Biology Research Center (F Heydarpour PhD), Health Institute (A Jalali PhD), Substance Abuse Prevention Research Center (A Jalali), Research Center for Environmental Determinants of Health (M Moradi PhD, Prof M Pirsaheb PhD, F Rajati PhD, Prof E Sadeghi PhD, Y Safari PhD, K Sharafi PhD), Clinical Research Development Center (M Naderi PhD), Department of Anatomical Sciences (M R Salahshoor PhD), Social Development and Health Promotion Research Center (Y Salimi PhD), Department of Epidemiology and Biostatistics (Y Salimi), Department of Sports Medicine and Rehabilitation (M Shamsi PhD), Department of Health Education and Health Promotion (S Siabani, A Ziapour PhD), Department of Vascular and Endovascular Surgery (M Sobhiyeh MD), Kermanshah University of Medical Sciences, Kermanshah, Iran; Department of Epidemiology (A Almasi-Hashiani PhD), Health Services Management Department (S Amini PhD), Department of Pediatrics (J Nazari MD), Arak University of Medical Sciences, Arak, Iran; Medical Research Center (H M Al-Mekhlafi PhD), Jazan University, Jazan, Saudi Arabia (Prof N Bedi MD); Department of Parasitology (H M Al-Mekhlafi), Sana'a University, Sana'a, Yemen; Pediatric Intensive Care Unit (K A Altirkawi MD, M Temsah MD), Internal Medicine Department (Y Mohammad MD), King Saud University, Riyadh, Saudi Arabia; Research Group in Health Economics (Prof N Alvis-Guzman PhD), University of Cartagena, Cartagena, Colombia; Research Group in Hospital Management and Health Policies (Prof N Alvis-Guzman), Department of Economic Sciences (N J Alvis-Zakzuk MSc), University of the Coast, Barranquilla, Colombia; National Health Observatory (N J Alvis-Zakzuk), Colombian National Health Observatory (C A Castañeda-Orjuela MD), National Institute of Health, Bogota, Colombia; Department of Epidemiology and Biostatistics (A L Amit BS), Department of Health Policy and Administration (C T Antonio MD, E A Faraon MD), Department of Nutrition (J F Lopez MD), University of the Philippines Manila, Manila, Philippines; School of Public Health (A L Amit), Center for Clinical Global Health Education (S R Atre PhD), Department of Epidemiology (A S Azman PhD), Neuroradiology Division (F Ghazi Sherbaf MD), Department of Radiology and Radiological Sciences (N Hafezi-Nejad), Johns Hopkins University, Baltimore, MD, United States; Lee Kuan Yew School of Public Policy (G H Amul MSc), National University of Singapore, Singapore, Singapore; Cardiology Department (C Andrei PhD), Department of General Surgery (I Negoi PhD), Department of Infectious Diseases (L Preotescu PhD), Carol Davila University of Medicine and Pharmacy, Bucharest, Romania; Social

Determinants of Health Research Center (M Anjomshoa PhD), Rafsanjan University of Medical Sciences, Rafsanjan, Iran; School of Public Health (A Ansariadi PhD), Hasanuddin University, Makassar, Indonesia; Department of Applied Social Sciences (C T Antonio), School of Nursing (P H Lee PhD), Hong Kong Polytechnic University, Hong Kong, China; Menzies Institute for Medical Research (B Antony PhD, A Singh M.Tech), University of Tasmania, Hobart, TAS, Australia; Agribusiness Study Program (E Antriyandarti Dr.Agr.Sc), Sebelas Maret University, Surakarta, Indonesia; Neurology Department (Prof H M A Aref PhD, Prof N El Nahas MD, Prof A S Shalash PhD), Department of Entomology (A M Samy PhD), Ain Shams University, Cairo, Egypt; Department of Public Health (O Aremu PhD), Birmingham City University, Birmingham, United Kingdom; Social Determinants of Health Research Center (B Armoon PhD), Saveh University of Medical Sciences, Saveh, Iran; Social Determinants of Health Research Center (B Armoon), Yasuj University of Medical Sciences, Yasuj, Iran; School of Health Sciences (A Arora PhD), Western Sydney University, Campbelltown, NSW, Australia; Disciple of Child and Adolescent Health (A Arora), University of Sydney, Westmead, NSW, Australia; Monitoring Evaluation and Operational Research Project (K K Aryal PhD), Abt Associates Nepal, Lalitpur, Nepal; School of Nursing and Midwifery (A Arzani DrPH), Social Determinants of Health Research Center (A Bijani PhD, S Mouodi PhD), Department of Clinical Biochemistry (A Mosapour PhD), Student Research Committee (M Zamani MD), Babol University of Medical Sciences, Babol, Iran (A Arzani); Department of Nursing (H T Atalay MSc, A Girmay MSc, D B Tadesse MSc, G T Weldesamuel MSc), School of Pharmacy (G T Demoz MSc, G G Kasahun MSc), Department of Biomedical Sciences (G G Kassa MSc), Aksum University, Aksum, Ethiopia; Department of Immunology (S Athari MPH), Zanjan University of Medical Sciences, Iran; Department of Biology (S Athari MPH), Department of Pharmacology and Toxicology (A Eftekhari PhD), Department of Microbiology (A Hasanzadeh), Maragheh University of Medical Sciences, Maragheh, Iran; Dr. D.Y. Patil Medical College, Hospital and Research Centre (S R Atre), Dr. D.Y. Patil Vidyapeeth, Pune, Pune, India; School of Business (Prof M Ausloos PhD), University of Leicester, Leicester, United Kingdom; Department of Statistics and Econometrics (Prof M Ausloos, Prof C Herteliu PhD, A Pana MD), Bucharest University of Economic Studies, Bucharest, Romania; King George's Medical University, Lucknow, India (Prof S Awasthi MD); Department of Nursing (N Awoke MSc), School of Public Health (T L Lenjebo MPH), Department of Midwifery (K Paulos MSc), Wolaita Sodo University, Wolaita Sodo, Ethiopia; The Judith Lumley Centre (B Ayala Quintanilla PhD), School of Nursing and Midwifery (M Rahman PhD), La Trobe University, Melbourne, VIC, Australia; School of Public Health (G Ayano MSc, D Hendrie PhD, T R Miller PhD), Curtin University, Perth, WA, Australia; Department of Health Policy Planning and Management (M A Ayanore PhD), Department of Family and Community Health (N Kugbey PhD), University of Health and Allied Sciences, Ho, Ghana; Department of Nursing (Y A Aynalem MSc, W S Shiferaw MSc), Debre Berhan University, Debre Berhan, Ethiopia; Public Health Risk Sciences Division (A Badawi PhD), Public Health Agency of Canada, Toronto, ON, Canada; Department of Nutritional Sciences (A Badawi), Centre for Global Child Health (Prof Z A Bhutta PhD), Department of Medicine (V Chattu MD), University of Toronto, Toronto, ON, Canada; Department of Chemistry (Prof M Bagherzadeh PhD, N Rabiee MSc), Sharif University of Technology, Tehran, Iran; Department of Forensic Medicine and Toxicology (S M Bakkannavar MD), Centre for Bio Cultural Studies (CBiCS) (P Hoogar PhD), Manipal Academy of Higher Education, Manipal, India (Prof V Jha MD); Department of Medical Microbiology (S Balakrishnan PhD), School of Nursing and Midwifery (A Desalew MSc), School of Public Health (M G Tekle MPH), Haramaya University, Harar, Ethiopia; Department of Hypertension (Prof M Banach PhD), Medical University of Lodz, Lodz, Poland; Polish Mothers' Memorial Hospital Research Institute, Lodz, Poland (Prof M Banach); Department of Internal Medicine (J A M Banoub MRCP), University of London, London, United Kingdom; Department of General Medicine (J A M Banoub), Pediatric Dentistry and Dental Public Health Department (Prof M El Tantawi PhD), Alexandria University, Alexandria, Egypt; Clinic for Infectious and Tropical Diseases (A Barac PhD), Clinical Center of Serbia, Belgrade, Serbia; Faculty of Medicine (A Barac, Prof M M Santric-Milicevic PhD), Institute of Microbiology and Immunology (E Dubljanin PhD), School of Public Health and Health Management (Prof M M Santric-Milicevic), University of Belgrade, Belgrade, Serbia; Department of Neurosciences (Prof M A Barboza MD), Costa Rican Department of Social Security, San Jose, Costa Rica; School of Medicine (Prof M A Barboza), University of Costa Rica, San Pedro, Costa Rica; Heidelberg Institute of Global Health (HIGH) (Prof T W Bärnighausen MD, J De Neve MD, B Moazen MSc, S Mohammed PhD), Heidelberg University, Heidelberg, Germany; T.H. Chan School of Public Health (Prof T W Bärnighausen), Center for Primary Care (S Basu PhD), Department of Global Health and Population (Prof O F Norheim PhD), Division of General Internal Medicine (Prof A Sheikh MD), Harvard University, Boston, MA, United States; School of Public Health (S Basu), Department of Primary Care and Public Health (J Car PhD, Prof A Majeed MD, Prof S Rawaf MD), Imperial College Business School (D Kusuma DSc), Imperial College London, London, United Kingdom; Faculty of Information Technology (V Bay PhD), Ho Chi Minh City University of Technology (HUTECH), Ho Chi Minh City, Vietnam; Health Human Resources Research Center (M Bayati PhD), Non-communicable Disease Research Center (Prof R Malekzadeh, S G Sepanlou), Shiraz University of Medical Sciences, Shiraz, Iran; Department of Community Medicine (Prof N Bedi), Gandhi Medical College Bhopal, Bhopal, India; Department of Physical Medicine and Rehabilitation (M Beheshti MD), Department of Epidemiology and Health Promotion (Prof H Benzian PhD), New York University, New York, NY, United States; Department of Epidemiology and Biostatistics (M Behzadifar MSc), Social Determinants of Health Research Center (M Behzadifar PhD), Department of Public Health (M Imani-Nasab PhD), Lorestan University of Medical Sciences, Khorramabad, Iran; Department of Medicine (D F Bejarano Ramirez BN), El Bosque University, Bogota, Colombia; Transplant Service (D F Bejarano Ramirez), University Hospital Foundation Santa Fe de Bogotá, Bogota, Colombia; School of the Environment (Prof M L Bell PhD), Yale University, New Haven, CT, United States; Nuffield Department of Population Health (D A Bennett PhD, B Lacey PhD), Centre for Tropical Medicine and Global Health (C Dolecek MD, S Lewycka PhD), Malaria Atlas Project (D J Weiss PhD), University of Oxford, Oxford, United Kingdom; Department of Public Health (D A Berbada MPH, Y C D Geramo MSc, D H Hayelom MSc, M B Sorrie MPH, F G W/hawariat MPH), Faculty of Business and Economics (G T Worku MPH), Arba Minch University, Arba Minch, Ethiopia; Hubert Department of Global Health (R S Bernstein MD), Emory University, Atlanta, GA, United States; Division of General Internal Medicine (A G Bhat MD), University of Massachusetts Medical School, Springfield, MA, United States; Department of Statistical and Computational Genomics (K Bhattacharyya MSc), National Institute of Biomedical Genomics, Kalyani, India; Department of Statistics (K Bhattacharyya), University of Calcutta, Kolkata, India; Injury Division (S Bhaumik MBBS), The George Institute for Global Health, New Delhi, India (Prof V Jha); The George Institute for Global Health (S Bhaumik), Transport and Road Safety (TARS) Research Centre (R Biswas MSc, S Boufous PhD), School of Public Health and Community Medicine (S Karki PhD), School of Optometry and Vision Science (Prof K Pesudovs PhD, Prof S Resnikoff MD), University of New South Wales, Sydney, NSW, Australia; Centre of Excellence in Women & Child Health (Prof Z A Bhutta), Division of Women and Child Health (J K Das MD), Aga Khan University, Karachi, Pakistan; Mario Negri Institute for Pharmacological Research, Ranica, Italy (B Bikbov MD); National Centre for Epidemiology and Population Health (M Bin Sayeed MSc, A Lal PhD), Research School of Population Health (K Wangdi PhD), Australian National University, Canberra, ACT, Australia; Department of Clinical Pharmacy and Pharmacology (M Bin Sayeed), University of Dhaka, Dhaka, Bangladesh; Department of Veterinary Medicine (S Bohlouli PhD), Islamic Azad University, Kermanshah, Iran; Department of Biomedical Technologies (A N Briko MSc), Bauman Moscow State Technical University, Moscow, Russia; Department of Epidemiology and Evidence Based Medicine (Prof N I Briko DSc, P D Lopukhov PhD), N. A. Semashko Department of Public Health and Healthcare (Prof M Jakovljevic PhD), Department of Information and Internet Technologies (Prof G Lebedev PhD), I.M. Sechenov First Moscow State Medical University, Moscow, Russia; Neuroscience Unit (G B Britton PhD), Institute for Scientific Research and High Technology Services, Panama City, Panama; Gorgas Memorial Institute for Health Studies, Panama City, Panama (G B Britton, F Castro MD, H Quintana PhD); Department of Community Medicine (Prof S Burugina Nagaraja MD), Employee State Insurance Post Graduate Institute of Medical Sciences and Research, Bangalore, India; School of Public Health and Health Systems (Z A Butt PhD), University of Waterloo, Waterloo, ON, Canada; Al Shifa School of Public Health (Z A Butt), Al Shifa Trust Eye Hospital, Rawalpindi, Pakistan; Internal Medicine Department (Prof L A Cámera MD), Hospital Italiano de Buenos Aires, Buenos Aires, Argentina; Board of Directors (Prof L A Cámera), Argentine Society of Medicine, Buenos Aires, Argentina (Prof P R Valdez M.Ed.); School of Medicine (J Campuzano Rincon), University of the Valley of Cuernavaca, Cuernavaca, Mexico; Centre for Population Health Sciences (J Car), Nanyang Technological University, Singapore, Singapore; Department of Health Care (Prof R Cárdenas DSc), Metropolitan Autonomous University, Mexico City, Mexico; Research Unit on Applied Molecular Biosciences (UCIBIO) (Prof F Carvalho PhD, V M Costa PhD), Associated Laboratory for Green Chemistry (LAQV) (Prof E Fernandes PhD), EPIUnit - Public Health Institute University Porto (ISPUP) (A Ribeiro PhD), University of Porto, Porto, Portugal; Epidemiology and Public Health Evaluation Group (C A Castañeda-Orjuela), Department of Public Health (Prof F P De la Hoz PhD), National University of Colombia, Bogota, Colombia; Mary MacKillop Institute for Health Research (Prof E Cerin PhD), Australian Catholic University, Melbourne, VIC, Australia; School of Public Health (Prof E Cerin), Centre for Suicide Research and Prevention (Prof P Yip PhD), Department of Social Work and Social Administration (Prof P Yip), University of Hong Kong, Hong Kong, China; Graduate School for International Development and Cooperation (B Chalise MPH), Hiroshima University, Hiroshima, Japan; Department of Epidemiology and Preventive Medicine (K L Chin PhD, Prof Y Guo PhD), School of Public Health and Preventive Medicine (S Li PhD, S Si PhD), The School of Clinical Sciences at Monash Health (S Zaman MPH), Monash University, Melbourne, VIC, Australia; Melbourne Medical School (K L Chin), University of Melbourne, Parkville, VIC, Australia; Department of Pulmonary Medicine (Prof D J Christopher MD), Department of Endocrinology, Diabetes and Metabolism (Prof N Thomas PhD), Department of Nephrology (Prof S Varughese FRCP), Christian Medical College and Hospital (CMC), Vellore, India; Faculty of Biology (D Chu PhD), Hanoi National University of Education, Hanoi, Vietnam; Discipline of Public Health (A F Dadi), College of Medicine and Public Health (H A Gesesew PhD), Southgate Institute for Health and Society (F H Tesfay PhD), Flinders University, Adelaide, SA, Australia; Department of Community Medicine (Prof T Dahiru MA, M B Sufiyan MD), Health Systems and Policy Research Unit (S Mohammed), Ahmadu Bello University, Zaria, Nigeria; Health Policy Research (M R Mathur PhD), Disease Burden Department (A ThekkePurakkal PhD), Indian Institute of Public Health (Prof S Zodpey PhD), Public Health Foundation of India, Gurugram, India (Prof R Dandona, Prof L Dandona MD, G Kumar PhD, D K Lal MD); Indian Council of Medical Research, New Delhi, India(Prof L Dandona); Institute for Global Health Innovations (A K Dang MD, G H Ha MBA, C T Nguyen MPH, H L T Nguyen MPH, H Q Pham MD), Duy Tan University, Hanoi, Vietnam; Department of Information Technology (A M Darwesh PhD), Department of Computer Science (M Hosseinzadeh PhD), University of Human Development, Sulaymaniyah, Iraq; Department of Pediatrics (A H Darwish Dip.Lang.Stud.), Tanta University, Tanta, Egypt; Toxoplasmosis Research Center (Prof A Daryani PhD), Department of Immunology (Prof A Rafiei PhD), Molecular and Cell Biology Research Center (Prof A Rafiei), Faculty of Medicine (S Rahimi), Mazandaran University of Medical Sciences, Sari, Iran; Department of Epidemiology and Biostatistics (R Das Gupta MPH), University of South Carolina, Columbia, SC, United States; James P Grant School of Public Health (R Das Gupta), BRAC University, Dhaka, Bangladesh; Central University Tami Nadu, Thiruvarur, India (Prof A P Dash DSc); Department of Population and Development (C A Dávila-Cervantes PhD), Latin American Faculty of Social Sciences Mexico, Mexico City, Mexico; Neonatal Nursing Department (D B Demissie MSc), Nursing Department (M T Haile MSc), St Paul's Hospital Millennium Medical College, Addis Ababa, Ethiopia; Department of Public Health (T Kolola MPH), Ambo University, Ambo, Ethiopia (D B Demissie); Wellcome Trust Brighton and Sussex Centre for Global Health Research (K Deribe PhD), Brighton and Sussex Medical School, Brighton, United Kingdom; School of Public Health (K Deribe), Department of Psychiatry (W Fekadu PhD), Department of Nursing and Midwifery (K B Gebremedhin MSc), Department of Pharmacology (D Z Wondafrash MSc), School of Allied Health Sciences (E Yisma MSc), Addis Ababa University, Addis Ababa, Ethiopia; Department of Community Medicine (Prof S D Dharmaratne), University of Peradeniya, Peradeniya, Sri Lanka; Department of Mathematical Demography & Statistics (P Dhillon PhD), Department of Population Studies (J Khan M.Phil., A Patle MPH), International Institute for Population Sciences, Mumbai, India (P Kumar PhD); Health Research Section (M Dhimal PhD), Nepal Health Research Council, Kathmandu, Nepal; Department of Microbiology (G P Dhungana MSc), Far Western University, Mahendranagar, Nepal; Faculty of Veterinary Medicine and Zootechnics (Prof D Diaz), Autonomous University of Sinaloa, Culiacan Rosales, Mexico; Department of Health Promotion and Education (I O Dipeolu PhD, S E Ibitoye MPH), Department of Community Medicine (O S Ilesanmi), Department of Medicine (Prof M O Owolabi), University of Ibadan, Ibadan, Nigeria; Center of Excellence in Public Health Nutrition (H T Do MD), Center of Excellence in Behavioral Medicine (C L Hoang B.Med.Sc.), Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam; Mahidol-Oxford Tropical Medicine Research Unit, Bangkok, Thailand (C Dolecek); School of Medicine (Prof K E Doyle PhD), Translational Health Research Institute (F A Ogbo PhD), Western Sydney University, Sydney, NSW, Australia; Health Sciences (Prof K E Doyle), Royal Melbourne Institute of Technology University, Melbourne, VIC, Australia; School of Medicine (Prof A R Duraes PhD), Institute of Collective Health (Prof D Rasella PhD), Federal University of Bahia, Salvador, Brazil; Department of Internal Medicine (Prof A R Duraes), Escola Bahiana de Medicina e Saúde Pública, Salvador, Brazil; School of Health Sciences (H A Edinur PhD), Universiti Sains Malaysia, Kubang Kerian, Kelantan, Malaysia; Centre Clinical Epidemiology and Biostatistics (A Effiong MB), Faculty of Health and Medicine (M N Khan MSc), University of Newcastle, Newcastle, NSW, Australia; Department of Pharmacology and Toxicology (A Eftekhari), The John Paul II Catholic University of Lublin, Lublin, Poland; Department of Clinical Pathology (Prof M El Sayed Zaki PhD), Mansoura University, Mansoura, Egypt; World Health (Z El-Khatib PhD), Université du Québec en Abitibi-Témiscamingue, Quebec, QC, Canada; Department of Community Medicine (H Elkout PhD), Tripoli University, Tripoli, Libya; Health Information (H Elkout), World Health Organization (WHO), Tripoli, Libya; Department of Microbiology and Immunology (S Enany PhD), Suez Canal University, Ismailia, Egypt; Department of Midwifery (D A Endalew MSc, A Yeshaneh MSc), Wolkite University, Wolkite, Ethiopia; Division of Cancer Epidemiology and Genetics (A Etemadi PhD), National Cancer Institute, Bethesda, MD, United States; Independent Consultant, Awka, Nigeria (O Ezekannagha PhD); International Institute for Tropical Agriculture, Ibadan, Nigeria (O Ezekannagha); College of Medicine (M Fareed PhD), Imam Mohammad Ibn Saud Islamic University, Riyadh, Saudi Arabia; Department of Psychology (Prof A Faro PhD), Federal University of Sergipe, São Cristóvão, Brazil; Department of Environmental Health Engineering (M Fazlzadeh), Social Determinants of Health Research Center (T Zahirian Moghadam PhD, H Zandian PhD), Department of Community Medicine (H Zandian), Ardabil University of Medical Science, Ardabil, Iran; National Institute for Stroke and Applied Neurosciences (Prof V L Feigin), Auckland University of Technology, Auckland, New Zealand; Research Center of Neurology, Moscow, Russia (Prof V L Feigin); Department of Psychiatry (W Fekadu), Department of Public Health Nutrition (N Fentahun PhD), Bahir Dar University, Bahir Dar, Ethiopia; Department of Neurobiology (S Fereshtehnejad PhD), Department of Medicine-Huddinge (D K Mohammad PhD), Global Public Health-Health Systems and Policy (HSP): Medicines Focusing Antibiotics (Prof A Pathak PhD), Karolinska Institutet, Stockholm, Sweden; Division of Neurology (S Fereshtehnejad), University of Ottawa, Ottawa, ON, Canada; Psychiatry Department (I Filip MD), Kaiser Permanente, Fontana, CA, United States; School of Health Sciences (I Filip), A.T. Still University, Mesa, AZ, United States; Institute of Gerontological Health Services and Nursing Research (F Fischer PhD), Ravensburg-Weingarten University of Applied Sciences, Weingarten, Germany; Unit for Population-Based Dermatology Research (Prof C Flohr PhD), Department of Twin Research and Genetic Epidemiology (M Mazidi PhD), King's College London, London, United Kingdom; Institute of Gerontology (N A Foigt PhD), National Academy of Medical Sciences of Ukraine, Kyiv, Ukraine; Department of Medical Parasitology (M Foroutan PhD), Abadan Faculty of Medical Sciences, Abadan, Iran; School of Public Health, Medical, and Veterinary Sciences (R C Franklin PhD), James Cook University, Douglas, QLD, Australia; Department of Dermatology (T Fukumoto PhD), Kobe University, Kobe, Japan; Department of Cardiovascular Medicine (M M Gad MD), Heart and Vascular Institute (A M Saad MD), Cleveland Clinic, Cleveland, OH, United States; Gillings School of Global Public Health (M M Gad), University of North Carolina Chapel Hill, Chapel Hill, NC, United States; Open, Distance and eLearning Campus (A M Gatotoh PhD, Prof P N Keiyoro PhD), Courseware Development and Production (A M Gatotoh), Department of Psychiatry (M Kumar PhD), School of Economics (M K Muriithi PhD), University of Nairobi, Nairobi, Kenya; Department of Nursing (R T Gayesa MSc), School of Nursing and Midwifery (H K Kasaye MSc), Department of Public Health (M T Yilma MPH), Wollega University, Nekemte, Ethiopia; Department of Epidemiology (H A Gesesew), Department of Biostatistics (K Gezae MSc), School of Public Health (G G Meles MPH, F H Tesfay), Department of Psychiatry (W M Metekiya MSc), Department of Microbiology and Immunology (S Muthupandian PhD), Department of Environmental Health and Behavioral Sciences (A A Werkneh MSc), Department of Pharmacology and Toxicology (D Z Wondafrash), Mekelle University, Mekelle, Ethiopia (H G Meles MPH, S W Tekelemedhin MPH); Adelaide Medical School (T K Gill PhD), Australian Research Centre for Population Oral Health (N Hariyani PhD), Robinson Research Institute (H Mohammed PhD), School of Public Health (Y M Tefera MSc), University of Adelaide, Adelaide, SA, Australia; Medical School (Prof P S Gill DM), Division of Health Sciences (O A Uthman PhD), University of Warwick, Coventry, United Kingdom; Discipline of Public Health Medicine (T G Ginindza PhD), University of KwaZulu-Natal, Durban, South Africa; Tuberculosis Biomarker Research Unit (A Goodridge PhD), Institute for Scientific Research and High Technology Services, City of Knowledge, Panama; Hudson College of Public Health (S V Gopalani MPH), University of Oklahoma Health Sciences Center, Oklahoma City, OK, United States; Department of Health and Social Affairs (S V Gopalani), Government of the Federated States of Micronesia, Palikir, Federated States of Micronesia; Center for Clinical and Epidemiological Research (A C Goulart PhD), University of São Paulo, Sao Paulo, Brazil; Department of Internal Medicine (A C Goulart, I S Santos PhD), Center for Clinical and Epidemiological Research, Hospital Universitário (I S Santos), Department of Psychiatry (Y Wang PhD), University of São Paulo, São Paulo, Brazil; Postgraduate Program in Epidemiology (Prof B N G Goulart DSc), Federal University of Rio Grande do Sul, Porto Alegre, Brazil; Department of Dermatology (A Grada MD), Boston University, Boston, MA, United States; School of Public Health (Prof M S Green PhD, Prof S Linn DrPH), University of Haifa, Haifa, Israel; Department of Family and Community Medicine (M I M Gubari PhD), University Of Sulaimani, Sulaimani, Iraq; Department of Microbiology (Prof H C Gugnani PhD), Department of Epidemiology (Prof H C Gugnani), Saint James School of Medicine, The Valley, Anguilla; Epidemiology Unit (D Guido PhD), Agency for Health Protection, Milan, Italy; Institute of Tropical Pathology and Public Health (IPTSP) (R A Guimarães MSc), Federal University of Goias, Goiânia, Brazil; Department of Epidemiology (Prof Y Guo), Binzhou Medical University, Yantai City, China; Medical Resources (Prof Rah Gupta MD), March of Dimes, Arlington, VA, United States; Health Policy, Management and Leadership (Prof Rah Gupta), West Virginia University School of Public Health, Morgantown, WV, United States; Department of Preventive Cardiology (Prof Raj Gupta MD), Eternal Heart Care Centre & Research Institute, Jaipur, India; Department of Medicine (Prof Raj Gupta), Mahatma Gandhi University Medical Sciences, Jaipur, India; Department of Public Health (J A Haagsma PhD), Erasmus University Medical Center, Rotterdam, Netherlands; Department of Psychology (B J Hall PhD), University of Macau, Macau, China; School of Health and Environmental Studies (Prof S Hamidi DrPH), Hamdan Bin Mohammed Smart University, Dubai, United Arab Emirates; Department of Public Health (D Handiso MPH), Wachemo University, Hossana, Ethiopia; Tabriz University of Medical Sciences, Tabriz, Iran (H Haririan PhD); Department of Dental Public Health (N Hariyani), Faculty of Public Health (S Martini PhD), Airlangga University, Surabaya, Indonesia; Department of Zoology and Entomology (A I Hasaballah PhD), Al Azhar University, Cairo, Egypt; Institute for Social Science Research (M Hasan MPH, A A Mamun PhD), ARC Centre of Excellence for Children and Families over the Life Course (M Hasan), The University of Queensland, Indooroopilly, QLD, Australia; Department of Primary and Interdisciplinary Care (H Y Hassen MPH), University Hospital Antwerp, Antwerp, Belgium; Department of Public Health (H Y Hassen, A Henok MPH), Mizan-Tepi University, Mizan Teferi, Ethiopia; Center for Environmental and Respiratory Health Research (B Heibati PhD), University of Oulu, Oulu, Finland; School of Business (Prof C Herteliu), London South Bank University, London, United Kingdom; Department of Public Health (H D d Hidru MPH, B E Tesfay MPH), Adigrat University, Adigrat, Ethiopia; Department for Health (T R Hird PhD), Department of Mathematical Sciences (P Moraga PhD), University of Bath, Bath, United Kingdom; Department of Pharmacology (N Hossain MPhil), Bangladesh Industrial Gases Limited, Tangail, Bangladesh; Institute of Research and Development (M Hosseinzadeh), Duy Tan University, Da Nang, Vietnam; College of Science and Engineering (Prof M Househ PhD), Hamad Bin Khalifa University, Doha, Qatar; Department of Epidemiology and Health Statistics (Prof G Hu PhD), Central South University, Changsha, China; Department of Public Health and Community Medicine (Prof A Humayun PhD), Shaikh Khalifa Bin Zayed Al-Nahyan Medical College, Lahore, Pakistan; Department of Internal Medicine (S A Hussain MD), Rochester General Hospital, Rochester, NY, United States; Department of Epidemiology (Prof M D Ilic PhD), Department of Global Health, Economics and Policy (Prof M Jakovljevic), University of Kragujevac, Kragujevac, Serbia; College of Public Health (U Iqbal PhD), Graduate Institute of Biomedical Informatics (D N A Ningrum MPH), Taipei Medical University, Taipei, Taiwan; Research Institute for Endocrine Sciences (S N Irvani MD), School of Management and Medical Education (N Jahanmehr PhD), Safety Promotion and Injury Prevention Research Center (N Jahanmehr), Department of Epidemiology (S Sabour PhD), Ophthalmic Research Center (M Yaseri), Shahid Beheshti University of Medical Sciences, Tehran, Iran (M Khayamzadeh MD); Institute for Physical Activity and Nutrition (S Islam PhD), Deakin University, Burwood, VIC, Australia; Sydney Medical School (S Islam), School of Veterinary Science (B B Singh PhD), University of Sydney, Sydney, NSW, Australia; School of Public Health and Community Medicine (Prof R Q Ivers PhD), University of New South Wales, Sydney, Australia; Postgraduate Institute of Medicine (A U Jayatilleke PhD), University of Colombo, Colombo, Sri Lanka; Faculty of Graduate Studies (A U Jayatilleke), Institute for Violence and Injury Prevention, Colombo, Sri Lanka; Autism Spectrum Disorders Research Center (E Jenabi PhD), Department of Environmental Health Engineering (M Khazaei PhD, M Leili PhD), Neurophysiology Research Center (H Komaki MD), Department of Biostatistics (N Mohammad Gholi Mezerji MSc), Hamadan University of Medical Sciences, Hamadan, Iran (Prof R Mohammadibakhsh PhD); Department of Community Medicine (R P Jha MSc), Dr. Baba Saheb Ambedkar Medical College & Hospital, Delhi, India; Department of Community Medicine (R P Jha), Banaras Hindu University, Varanasi, India; Environmental Research Center (J S Ji DSc), Duke Kunshan University, Kunshan, China; Nicholas School of the Environment (J S Ji), Duke Global Health Institute (S Zadey MS), Duke University, Durham, NC, United States; Department of Ophthalmology (Prof J B Jonas MD), Heidelberg University, Mannheim, Germany; Beijing Institute of

Ophthalmology (Prof J B Jonas), Beijing Tongren Hospital, Beijing, China; Department of Family Medicine and Public Health (J J Jozwiak PhD), University of Opole, Opole, Poland; School of Public Health (Z Kabir PhD), University College Cork, Cork, Ireland; Department of Forensic Medicine and Toxicology (T Kanchan MD), All India Institute of Medical Sciences, Jodhpur, India; Institute for Epidemiology and Social Medicine (A Karch MD), University of Münster, Münster, Germany; International Research Center of Excellence (G A Kayode PhD), Institute of Human Virology Nigeria, Abuja, Nigeria; Julius Centre for Health Sciences and Primary Care (G A Kayode), Institute for Risk Assessment Sciences (IRAS) (E Traini MSc), Utrecht University, Utrecht, Netherlands; Department of Cancer Epidemiology (M M Kebede PhD), German Cancer Research Center, Heidelberg, Germany; Department of Prevention and Evaluation (M M Kebede), Leibniz Institute for Prevention Research and Epidemiology, Bremen, Germany; Department of Public Health (Prof Y S Khader PhD), Jordan University of Science and Technology, Irbid, Jordan; School of Food and Agricultural Sciences (N Khalid PhD), University of Management and Technology, Lahore, Pakistan; Department of Biophysics and Molecular Biology (Prof R Khalilov PhD), Baku State University, Baku, Azerbaijan; Institute of Radiation Problems (Prof R Khalilov), Azerbaijan National Academy of Sciences, Baku, Azerbaijan; Department of Epidemiology and Biostatistics (E A Khan MPH), Health Services Academy, Islamabad, Pakistan; Department of Population Sciences (M N Khan), Jatiya Kabi Kazi Nazrul Islam University, Mymensingh, Bangladesh; Faculty of Health and Wellbeing (K Khatab PhD), Sheffield Hallam University, Sheffield, United Kingdom; College of Arts and Sciences (K Khatab), Ohio University, Zanesville, OH, United States; The Iranian Academy of Medical Sciences, Tehran, Iran (M Khayamzadeh); Department of Nutrition and Health Science (Prof J Khubchandani PhD), Ball State University, Muncie, IN, United States; Clinical Epidemiology Unit (A Kiadaliri PhD), Lund University, Lund, Sweden; School of Traditional Chinese Medicine (Y Kim PhD), Xiamen University Malaysia, Sepang, Malaysia; Department of Nutrition (R W Kimokoti MD), Simmons University, Boston, MA, United States; Department of Nursing and Health Promotion (S Kisa PhD), Oslo Metropolitan University, Oslo, Norway; School of Health Sciences (Prof A Kisa PhD), Kristiania University College, Oslo, Norway; Global Community Health and Behavioral Sciences (Prof A Kisa), Tulane University, New Orleans, LA, United States; Global Healthcare Consulting, New Delhi, India (S Kochhar); Brain Engineering Research Center (H Komaki), Institute for Research in Fundamental Sciences, Tehran, Iran; Independent Consultant, Jakarta, Indonesia (S Kosen MD); Department of Internal and Pulmonary Medicine (Prof P A Koul MD), Sheri Kashmir Institute of Medical Sciences, Srinagar, India; CIBERSAM (A Koyanagi MD), San Juan de Dios Sanitary Park, Sant Boi de Llobregat, Spain; Catalan Institution for Research and Advanced Studies (ICREA), Barcelona, Spain (A Koyanagi); Department of Anthropology (K Krishan PhD), Panjab University, Chandigarh, India; Department of Demography (Prof B Kuate Defo PhD), Department of Social and Preventive Medicine (Prof B Kuate Defo), University of Montreal, Montreal, QC, Canada; Division of Psychology and Language Sciences (M Kumar), University College London, London, United Kingdom; Faculty of Public Health (D Kusuma), University of Indonesia, Depok, Indonesia; Department of Clinical Sciences and Community Health (Prof C La Vecchia MD), University of Milan, Milan, Italy; National Institute for Health Research (NIHR) Oxford Biomedical Research Centre, Oxford, United Kingdom (B Lacey); Institute of Health Policy and Development Studies (Prof H Lam PhD), National Institutes of Health, Manila, Philippines; Department of Community and Family Medicine (F H Lami PhD), University of Baghdad, Baghdad, Iraq; Medical Director (Prof V C Lansingh PhD), HelpMeSee, New York, NY, United States; General Director (Prof V C Lansingh), Mexican Institute of Ophthalmology, Queretaro, Mexico; Department of Otorhinolaryngology (S Lasrado MS), Father Muller Medical College, Mangalore, India; Federal Research Institute for Health Organization and Informatics of the Ministry of Health (FRIHOI), Moscow, Russia (Prof G Lebedev); School of Public Health (C T Leshargie MPH), Haramaya University, Debre Markos, Ethiopia; Oxford University Clinical Research Unit (S Lewycka), Wellcome Trust Asia Programme, Hanoi, Vietnam; Chinese Center for Disease Control and Prevention, Beijing, China (Prof S Liu PhD); Alliance for Improving Health Outcomes, Quezon City, Philippines (J F Lopez); Ophthalmology Department (M Magdy Abd El Razek MSc), Ministry of Health & Population, Aswan, Egypt; Department of Forensic Medicine & Toxicology (D Mahadeshwara Prasad MD), Mysore Medical College & Research Institute, Mysooru, India; Department of Health & Family Welfare (D Mahadeshwara Prasad), Government of Karnataka, India; Department of Clinical Physiology (N B Mahotra MD), Tribhuvan University, Kathmandu, Nepal; School of Medicine (N Manafi), University of Manitoba, Winnipeg, MB, Canada; Department of Population Studies (C Mapoma PhD), University of Zambia, Lusaka, Zambia; Department of Economics (Prof G Martinez PhD), Autonomous Technology Institute of Mexico, Mexico City, Mexico; Indonesian Public Health Association, Surabaya, Indonesia (S Martini); Campus Caucaia (F R Martins-Melo PhD), Federal Institute of Education, Science and Technology of Ceará, Caucaia, Brazil; Institute of Population Health Sciences (M R Mathur PhD), University of Liverpool, Liverpool, United Kingdom; ICF International (B K Mayala), DHS Program, Rockville, MD, United States; Department of Ophthalmology (C McAlinden PhD), Singleton Hospital, Swansea, United Kingdom; Department of Pharmacy (B Meharie MSc), Department of Public Health (T C Mekonnen MPH), Department of Environmental Health (Y M Tefera), Wollo University, Dessie, Ethiopia; Neurology Department (Prof M Mehndiratta MD), Janakpuri Super Specialty Hospital Society, New Delhi, India; Department of Neurology (Prof M Mehndiratta), Govind Ballabh Institute of Medical Education and Research, New Delhi, India; Department of Epidemiology and Biostatistics (K M Mehta DSc), University of California San Francisco, San Francisco, CA, United States; Department of Nutrition (T Mekonnen MPH), University of Oslo, Oslo, Norway; Institute of Human Virology (P T N Memiah DrPH), School of Medicine (M T Wallin MD), University of Maryland, Baltimore, MD, United States; College of Medicine (Prof Z A Memish MD), Alfaisal University, Riyadh, Saudi Arabia; Research & Innovation Center (Prof Z A Memish), Ministry of Health, Riyadh, Saudi Arabia; Peru Country Office (W Mendoza MD), United Nations Population Fund (UNFPA), Lima, Peru; Breast Surgery Unit (T J Meretoja MD), Helsinki University Hospital, Helsinki, Finland; University of Helsinki, Helsinki, Finland (T J Meretoja); Clinical Microbiology and Parasitology Unit (T Mestrovic PhD), Dr. Zora Profozic Polyclinic, Zagreb, Croatia; University Centre Varazdin (T Mestrovic), University North, Varazdin, Croatia; Center for Innovation in Medical Education (B Miazgowski MD), Pomeranian Medical University, Szczecin, Poland (B Miazgowski); Pacific Institute for Research & Evaluation, Calverton, MD, United States (T R Miller); Global Institute of Public Health (Prof G Mini PhD), Ananthapuri Hospitals and Research Institute, Trivandrum, India; Women's Social and Health Studies Foundation, Trivandrum, India (Prof G Mini); Internal Medicine Programme (Prof E M Mirrakhimov PhD), Kyrgyz State Medical Academy, Bishkek, Kyrgyzstan; Department of Atherosclerosis and Coronary Heart Disease (Prof E M Mirrakhimov), National Center of Cardiology and Internal Disease, Bishkek, Kyrgyzstan; Institute of Addiction Research (ISFF) (B Moazen), Frankfurt University of Applied Sciences, Frankfurt, Germany; Department of Forestry (D K Mohammad), Salahaddin University-Erbil, Erbil, Iraq; Department of Public Health (J A Mohammed MPH), Samara University, Semera, Ethiopia; Health and Environmental Sciences Department (Y Moodley PhD), Central University of Technology, Bloemfontein, South Africa; Social Determinants of Health Research Center (G Moradi PhD), Department of Epidemiology and Biostatistics (G Moradi), Kurdistan University of Medical Sciences, Sanandaj, Iran; National Center for Health Insurance Research (M Moradi-Joo PhD), Iran Health Insurance Organization, Tehran, Iran; Department of Clinical Biochemistry (A Mosapour), Tarbiat Modares University, Tehran, Iran; Department of Biochemistry (M Mozaffor MD), Medical College for Women & Hospital, Dhaka, Bangladesh; Biomedical Research Foundation, Dhaka, Bangladesh (M Mozaffor); School of Medical Sciences (K Musa PhD), Science University of Malaysia, Kubang Kerian, Malaysia; Department of Pediatric Medicine (Prof G Mustafa MD), The Children's Hospital & The Institute of Child Health, Multan, Pakistan; Department of Pediatrics & Pediatric Pulmonology (Prof G Mustafa), Institute of Mother & Child Care, Multan, Pakistan; Research and Analytics

Department (A J Nagarajan M.Tech), Initiative for Financing Health and Human Development, Chennai, India; Department of Research and Analytics (A J Nagarajan), Bioinsilico Technologies, Chennai, India; Comprehensive Cancer Center (G Naik MPH), Department of Psychology (D C Schwebel PhD), School of Medicine (Prof J A Singh MD), University of Alabama at Birmingham, Birmingham, AL, United States; Suraj Eye Institute, Nagpur, India (V Nangia MD); Department of General Surgery (I Negoi), Emergency Hospital of Bucharest, Bucharest, Romania; School of Health Sciences, Surgical Nursing (H B Netsere), Bahir Dar University, Gondar, Ethiopia; Department of Biological Sciences (J W Ngunjiri DrPH), University of Embu, Embu, Kenya; Public Health Department (D N A Ningrum), Universitas Negeri Semarang, Kota Semarang, Indonesia; School of Public Health and Family Medicine (C A Nnaji, Prof C S Wiysonge), Department of Paediatrics & Child Health (Prof H J Zar PhD), University of Cape Town, Cape Town, South Africa; Department of Global Public Health and Primary Care (Prof O F Norheim), University of Bergen, Bergen, Norway; Centre for Heart Rhythm Disorders (J Noubiap MD), University of Adelaide, Adelaide, WA, Australia; Administrative and Economic Sciences Department (Prof B Oancea PhD), University of Bucharest, Bucharest, Romania; Department of Preventive Medicine (I Oh PhD), Kyung Hee University, Dongdaemun-gu, South Korea; Department of Psychiatry and Behavioural Neurosciences (A T Olagunju MD), Population Health Research Institute (T Sathish PhD), McMaster University, Hamilton, ON, Canada; Department of Psychiatry (A T Olagunju), University of Lagos, Lagos, Nigeria; Centre for Healthy Start Initiative, Lagos, Nigeria (B O Olusanya PhD, J O Olusanya MBA); Department of Pharmacology and Therapeutics (Prof O E Onwujekwe PhD), Department of Community Medicine (Prof B S Uzochukwu MD), University of Nigeria Nsukka, Enugu, Nigeria; Department of Environmental Management and Toxicology (O Osarenotor MSc), University of Benin, Benin City, Nigeria; Faculty of Geo-Information Science and Earth Observation (F B Osei PhD), University of Twente, Enschede, Netherlands; Department of Mathematics and Statistics (F B Osei), University of Energy and Natural Resources, Sunyani, Ghana; Department of Respiratory Medicine (Prof M P A DNB), Jagadguru Sri Shivarathreeswara Academy of Health Education and Research, Mysore, India; Department of Forensic Medicine (J Padubidri MD), Department of Forensic Medicine and Toxicology (Prof B K Shetty MD), Kasturba Medical College (Prof B Unnikrishnan MD), Manipal Academy of Higher Education, Mangalore, India; Department of Medicine (S Pakhale MD), Ottawa Hospital Research Institute, Ottawa, ON, Canada; Department of Health Metrics (A Pana), Center for Health Outcomes & Evaluation, Bucharest, Romania; Department of Medical Humanities and Social Medicine (Prof E Park PhD), Kosin University, Busan, South Korea; Department of Poverty, Gender and Youth (S K Patel PhD), Population Council, New Delhi, India; Department of Pediatrics (Prof A Pathak), RD Gardi Medical College, Ujjain, India; International Institute of Health Management Research, New Delhi, India (A Patle); Center for Research and Innovation (V F Pepito MSc), Ateneo De Manila University, Pasig City, Philippines; Mario Negri Institute for Pharmacological Research, Bergamo, Italy (N Perico MD, Prof G Remuzzi MD); Field Epidemiology and Laboratory Training Program (A Pervaiz MSc), National Institute of Health Islamabad, Islamabad, Pakistan; Center for Integration of Data and Health Knowledge (J M Pescarini PhD), Oswaldo Cruz Foundation, Salvador, Brazil; Department of Cardiology (T Pilgrim MD), University of Bern, Bern, Switzerland; Institute of Microbiology and Immunology (Prof M Poljak PhD), University of Ljubljana, Ljubljana, Slovenia; University Medical Center Groningen (Prof M J Postma PhD), School of Economics and Business (Prof M J Postma), University of Groningen, Groningen, Netherlands; School of Population and Public Health (F Pourmalek PhD, Prof N Sarrafzadegan), University of British Columbia, Vancouver, BC, Canada; Clinical Research Center (S I Prada PhD), Fundación Valle del Lili, Cali, Colombia; Center for Studies in Social Protection and Health Economics (S I Prada), ICESI University, Cali, Colombia; National Institute of Infectious Diseases, Bucuresti, Romania (L Preotescu); Biomedical Engineering Department (Prof M Rabiee PhD), Amirkabir University of Technology, Tehran, Iran; College of Medicine (A Radfar MD), University of Central Florida, Orlando, FL, United States; Department of Community Medicine (M Rahman PhD), Maharishi Markandeshwar Institute of Medical Sciences & Research, Ambala, India; School of Nursing and Healthcare Professions (M Rahman), Federation University Australia, Berwick, VIC, Australia; Research Department (C L Ranabhat PhD), Policy Research Institute, Kathmandu, Nepal; Health and Public Policy Department (C L Ranabhat), Global Center for Research and Development, Kathmandu, Nepal; Department of Radiation Oncology (Prof G K Rath MD), Department of Psychiatry (Prof R Sagar MD), All India Institute of Medical Sciences, New Delhi, India; Academic Public Health England (Prof S Rawaf), Public Health England, London, United Kingdom; School of Health, Medical and Applied Sciences (L Rawal PhD), CQ University, Sydney, NSW, Australia; River Region Cardiology Associates, Montgomery, WV, United States (W F Rawasia MD); School of Nursing and Midwifery (V Renjith PhD), Royal College of Surgeons in Ireland - Bahrain, Muharraq Governorate, Bahrain; School of Social Sciences and Psychology (Prof A M N Renzaho PhD), Translational Health Research Institute (Prof A M N Renzaho), Western Sydney University, Penrith, NSW, Australia; Brien Holden Vision Institute, Sydney, Australia (Prof S Resnikoff); Cardiovascular Diseases Research Center (S Riahi PhD), Birjand University of Medical Sciences, Birjand, Iran; Department of Surgery (J Rickard MD), University of Minnesota, Minneapolis, MN, United States; Department of Surgery (J Rickard), University Teaching Hospital of Kigali, Kigali, Rwanda; Department of Clinical Research (L Roever PhD), Federal University of Uberlândia, Uberlândia, Brazil; Clinical Epidemiology and Public Health Research Unit (L Ronfani PhD), Burlo Garofolo Institute for Maternal and Child Health, Trieste, Italy; Agrosavia, Palmira, Colombia (E Rubagotti PhD); Department of Biomedical Sciences (Prof S Rubino PhD), University of Sassari, Sassari, Italy; Department of Phytochemistry (Prof S Sajadi PhD), Soran University, Soran, Iraq; Department of Nutrition (Prof S Sajadi), Cihan University-Erbil, Kurdistan Region, Iraq; Department of Microbiology (N Salam PhD), Central University of Punjab, Bathinda, India; School of Pharmacy (A Saleem PharmD), The University of Queensland, Brisbane, QLD, Australia; Public Health and Community Medicine Department (M R Salem MD), Cairo University, Giza, Egypt; Department of Surgery (Prof J Sanabria MD), Marshall University, Huntington, WV, United States; Department of Nutrition and Preventive Medicine (Prof J Sanabria), Case Western Reserve University, Cleveland, OH, United States; Department of Community Medicine (S Y Saraswathy PhD), PSG Institute of Medical Sciences and Research, Coimbatore, India; PSG-FAIMER South Asia Regional Institute, Coimbatore, India (S Y Saraswathy); Department of Geriatrics and Long Term Care (B Sathian PhD), Hamad Medical Corporation, Doha, Qatar; Faculty of Health & Social Sciences (B Sathian), Bournemouth University, Bournemouth, United Kingdom; UGC Centre of Advanced Study in Psychology (M Satpathy PhD), Utkal University, Bhubaneswar, India; Udyam-Global Association for Sustainable Development, Bhubaneswar, India (M Satpathy); Department of Public Health Sciences (M Sawhney PhD), University of North Carolina at Charlotte, Charlotte, NC, United States; Department of Food Science and Nutrition (A M Senbeta MSc), Jigjiga University, Jigjiga, Ethiopia; Emergency Department (S Senthilkumaran MD), Manian Medical Centre, Erode, India; Department of Cardiology (A Shafieesabet MD), Charité Medical University Berlin, Berlin, Germany; Center for Stroke Research Berlin (CSB), Berlin, Germany (A Shafieesabet); Public Health Division (A A Shaheen PhD), An-Najah National University, Nablus, Palestine; Department of Internal Medicine (I Shahid MBBS), Ziauddin University, Karachi, Pakistan; Independent Consultant, Karachi, Pakistan (M A Shaikh MD); School of Medicine (M Shams-Beyranvand MSc), Alborz University of Medical Sciences, Karaj, Iran; Faculty of Caring Science, Work Life, and Social Welfare (M Shamsizadeh MSc), Faculty of Caring Science, Work Life and Social Welfare, University of Borås, Borås, Sweden, Borås, Sweden; Department of Community Medicine (M Shannawaz PhD), BLDE University, Vijayapur, India; University School of Management and Entrepreneurship (R Sharma PhD), Delhi Technological University, Delhi, India; Centre for Medical Informatics (Prof A Sheikh), Public Health Department (T A Zerfu PhD), University of Edinburgh, Edinburgh, United Kingdom; National Institute of Infectious Diseases, Tokyo, Japan (M Shigematsu PhD); College of Medicine (Prof J Shin MD), Yonsei University, Seoul, South Korea; Finnish Institute of Occupational Health, Helsinki, Finland (R Shiri PhD); Public Health Dentistry Department (Prof K M Shivakumar PhD), Krishna Institute of Medical Sciences Deemed to be University, Karad, India; Department of Medicine (T J Siddiqi MB), Department of Internal Medicine (M S Usman MB), Dow University of Health Sciences, Karachi, Pakistan; Department of Physical Education (Prof D A S Silva PhD), Federal University of Santa Catarina, Florianopolis, Brazil; School of Public Health & Zoonoses (B B Singh), Guru Angad Dev Veterinary & Animal Sciences University, Ludhiana, India; Department of Pulmonary Medicine (Prof V Singh MD), Asthma Bhawan, Jaipur, India; Max Hospital, Ghaziabad, India (Prof N P Singh MD); Medicine Service (Prof J A Singh), US Department of Veterans Affairs (VA), Birmingham, AL, United States; Department of Epidemiology (D N Sinha PhD), School of Preventive Oncology, Patna, India; Department of Epidemiology (D N Sinha), Healis Sekhsaria Institute for Public Health, Mumbai, India; Department of Ophthalmology (E Skiadaresi MD), Hywel Dda University Health Board, Llanelli, United Kingdom; Department of Diseases and Non-communicable Diseases and Health Promotion (A M Soares Filho DSc), Federal Ministry of Health, Brasília, Brazil; Health Surveillance Secretariat (A M Soares Filho), Ministry of Health, Brasília, Brazil; Department of Infectious Diseases (A Sokhan PhD), Kharkiv National Medical University, Kharkiv, Ukraine; Princess University Hospital (Prof J B Soriano MD), Autonomous University of Madrid, Madrid, Spain; Centro de Investigación Biomédica en Red Enfermedades Respiratorias (CIBERES), Madrid, Spain (Prof J B Soriano); Hull York Medical School (I N Soyiri PhD), University of Hull, Hull City, United Kingdom; Division of Community Medicine (C T Sreeramareddy MD), International Medical University, Kuala Lumpur, Malaysia; Nursing (A Sudaryanto MPH), Muhammadiyah University of Surakarta, Surakarta, Indonesia; Department of Agriculture and Food Systems (H Suleria PhD), Department of Neurology (Prof T Wijeratne MD), University of Melbourne, Melbourne, VIC, Australia; Department of Criminology, Law, and Society (Prof B L Sykes PhD), University of California Irvine, Irvine, CA, United States; Department of Medicine (Prof R Tabarés-Seisdedos PhD), University of Valencia, Valencia, Spain; Carlos III Health Institute (Prof R Tabarés-Seisdedos), Biomedical Research Networking Center for Mental Health Network (CiberSAM), Madrid, Spain; Cancer Control Center (T Tabuchi MD), Osaka International Cancer Institute, Osaka, Japan; Research and Development Center for Humanities and Health Management (I U Tarigan PhD), National Institute of Health Research & Development, Jakarta, Indonesia; Colgate University, Hamilton, NY, United States (B Taye PhD); Department of Public Health and Community Medicine (Prof K R Thankappan MD), Central University of Kerala, Kasaragod, India; Department of Global Health Research (A J Thomson PhD), Adaptive Knowledge Management, Victoria, BC, Canada; Institute of Public Health (R Topor-Madry PhD), Jagiellonian University Medical College, Kraków, Poland; Agency for Health Technology Assessment and Tariff System, Warsaw, Poland (R Topor-Madry); Department of Pathology and Legal Medicine (M R Tovani-Palone PhD), University of São Paulo, Ribeirão Preto, Brazil; Modestum LTD, London, United Kingdom (M R Tovani-Palone); Department of Health Economics (B X Tran PhD), Hanoi Medical University, Hanoi, Vietnam; Molecular Medicine and Pathology (K B Tran MD), University of Auckland, Auckland, New Zealand; Clinical Hematology and Toxicology (K B Tran), Maurice Wilkins Centre, Auckland, New Zealand; Department of Allied Health Sciences (I Ullah PhD), Iqra National University, Peshawar, Pakistan; Velez Sarsfield Hospital, Buenos Aires, Argentina (Prof P R Valdez); Psychosocial Injuries Research Center (Y Veisani PhD), Ilam University of Medical Sciences, Ilam, Iran; Department of Medical and Surgical Sciences (Prof F S Violante MD), University of Bologna, Bologna, Italy; Occupational Health Unit (Prof F S Violante), Sant'Orsola Malpighi Hospital, Bologna, Italy; Department of Economics (Prof S Vollmer PhD), University of Göttingen, Göttingen, Germany; Foundation University Medical College (Prof Y Waheed PhD), Foundation University Islamabad, Islamabad, Pakistan; Department of Neurology (M T Wallin), George Washington University, Washington, DC, United States; Department of Epidemiology and Biostatistics (Y Wang BSA, Prof C Yu PhD), Global Health Institute (Prof C Yu), Wuhan University, Wuhan, China; Competence Center of Mortality-Follow-Up of the German National Cohort (R Westerman DSc), Federal Institute for Population Research, Wiesbaden, Germany; Department of Physical Therapy (T Wiangkham PhD), Naresuan University, Phitsanulok, Thailand; Department of Medicine (Prof T Wijeratne), University of Rajarata, Saliyapura Anuradhapuraya, Sri Lanka; Department of Health Economics (G T Worku), Addis Continental Institute of Public Health, Addis Ababa, Ethiopia; Clinical Cancer Research Center (S Yahyazadeh Jabbari MD), Milad General Hospital, Tehran, Iran; Department of Diabetes and Metabolic Diseases (T Yamada MD), University of Tokyo, Tokyo, Japan; Department of Public Health (Prof H Yatsuya PhD), Fujita Health University, Toyoake, Japan; Department of Public Health and Health Systems (Prof H Yatsuya), Nagoya University, Nagoya, Japan; Department of Neuropsychopharmaology (N Yonemoto MPH), National Center of Neurology and Psychiatry, Kodaira, Japan; Department of Public Health (N Yonemoto), Juntendo University, Tokyo, Japan; Department of Health Policy and Management (Prof M Z Younis PhD), Jackson State University, Jackson, MS, United States; School of Medicine (Prof M Z Younis), Tsinghua University, Beijing, China; Department of Health care Management and Economics (H Yusefzadeh PhD), Urmia University of Medical Science, Urmia, Iran; Department of Medicine (Prof Z Zaidi PhD), University Ferhat Abbas of Setif, Sétif, Algeria; Maternal and Child Health Division (S Zaman), International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka, Bangladesh; Unit on Child & Adolescent Health (Prof H J Zar), Medical Research Council South Africa, Cape Town, South Africa; College of Medicine and Health Sciences (T A Zerfu), Dilla University, Dilla, Ethiopia; School of Public Health (Y Zhang PhD), Hubei Province Key Laboratory of Occupational Hazard Identification and Control (Y Zhang), Wuhan University of Science and Technology, Wuhan, China; Health Technology Assessment Unit (Y H Zuniga BS), Department of Health Philippines, Manila, Philippines; #MentalHealthPH, Quezon City, Philippines (Y H Zuniga)

Contributors

AD, PL, MB, GCG, AB, and JA collected and cleaned the data. AD and PL vetted the data. AD produced estimates and AD, RCR, and KEW vetted the models and the results. AD and MMP prepared the first draft of the manuscript. AD, KJ, MB, and PL constructed the figures and tables. RCR and SIH provided overall guidance. BFB, PCR, RCR, and SIH managed the project. AD, MMP, MB, BFB, and GIH finalised the manuscript on the basis of comments from other authors and reviewer feedback. AD, PL, MB, and GIH managed the appendix. All other authors provided data, reviewed results, initiated modelling infrastructure, or reviewed and contributed to the study.

Declaration of interests

This study was funded by the Bill & Melinda Gates Foundation. Co-authors employed by the Gates Foundation provided feedback on initial mapped estimates and drafts of this manuscript. MLB reports grants from US Environmental Protection Agency, National Institutes of Health (NIH), and the Wellcome Trust Foundation, during the conduct of the study; and honoraria or travel reimbursement from NIH (for review of grant proposals), American Journal of Public Health (participation as editor), Global Research Laboratory and Seoul National University, Royal Society (London, UK), Ohio University, Atmospheric Chemistry Gordon Research Conference, Johns Hopkins, Bloomberg School of Public Health, Arizona State University, Ministry of the Environment, Japan, Hong Kong Polytechnic University, University of Illinois—Champaign, and University of Tennessee—Knoxville, outside of the submitted work. AD reports grants from the Gates Foundation, during the conduct of the study. CF reports grants from European Union IMI grant scheme (Horizon 2020), outside the submitted work. SMSI reports grants from National Heart Foundation of Australia, Institute for Physical Activity and Nutrition, and Deakin University, during the conduct of the study. RQI reports grants from National Health and Medical Research Council of Australia, during the conduct of the study. VJ reports grants from Baxter Healthcare, GlaxoSmithKline, NephroPlus, and Zydus Cadilla, and personal fees from AstraZeneca,

outside of the submitted work. JJJ reports personal fees from Amgen, ALAB Laboratoria, Teva, Synexus, and Boehringer Ingelheim, outside of the submitted work. KKr reports grants from UGC Center of Advanced Study (CAS II), Department of Anthropology, Panjab University, Chandigarh, India, outside the submitted work. WM is a Program Analyst in Population and Development at the UNFPA Country Office in Peru, an institution which does not necessarily endorse this study. JFM reports grants from the Gates Foundation, during the conduct of the study. TP reports grants and personal fees from Boston Scientific, grants and personal fees from Biotronik, personal fees from HighLife SAS, outside the submitted work. MJP holds stocks in Ingress Health and Pharmacoeconomics Advice Groningen and is advisor to Asc Academics, all pharmacoeconomic consultancy companies. MJP reports grants and personal fees from Merck Sharpe & Dohme, GlaxoSmithKline, Pfizer, Boehringer Ingelheim, Novavax, Bristol-Myers Squibb, AstraZeneca, Sanofi, IQVIA, Seqirus, Quintiles, Nocartis, and Pharmerit; grants from Bayer, BioMerieux, WHO, EU, FIND, Antilope, DIKTI, LPDP, and Budi; and other support from Ingress Health, Pharmacoeconomics Advice Groningen, and Asc Academics, outside of the submitted work. JAS reports personal fees from Crealta/Horizon, Medisys, Fidia, UBM, Trio health, Medscape, WebMD, Clinical Care options, Clearview Healthcare Partners, Putnam Associates, Spherix, Practice Point Communications, NIH, American College of Rheumatology, and Simply Speaking; other support from Amarin Pharmaceuticals and Viking Pharmaceuticals; non-financial support from FDA Arthritis Advisory Committee, Steering committee of OMERACT (an international organisation that develops measures for clinical trials and receives arms-length funding from 12 pharmaceutical companies), Veterans Affairs Rheumatology Field Advisory Committee, outside of the submitted work. JAS is editor and director of the UAB Cochrane Musculoskeletal Group Satellite Center on Network Meta-analysis. All other authors declare no competing interests.

Data sharing

The source code used to generate estimates is available online. The study data, including full sets of estimates at the first and second administrative levels, are also available online.

For the **source code** see https://github.com/ihmeuw/lbd/tree/wash-lmic-2020

For the **study data** see http://ghdx.healthdata.org/record/ihme-data/lmic-wash-access-geospatial-estimates-2000-2017

Acknowledgments

This work was primarily supported by a grant from the Gates Foundation (OPP1132415). LGA has received support from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Finance Code 001), Conselho Nacional de Desenvolvimento Científico e Tecnológico and Fundação de Amparo à Pesquisa do Estado de Minas Gerais. OOA acknowledges the Department of Science and Innovation, National Research Foundation, and DSI/NRF Centre of Excellence for Epidemiological Modelling and Analysis, Stellenbosch, South Africa. SMAl acknowledges the Department of Health Policy and Management, Faculty of Public Health, Kuwait University and International Centre for Casemix and Clinical Coding, Faculty of Medicine, National University of Malaysia for the approval and support to participate in this research project. HTA acknowledges Aksum University. MAu and CH are partly supported by a grant from the Romanian National Authority for Scientific Research and Innovation, CNDS-UEFISCDI, project number PN-III-P4-ID-PCCF-2016-0084. AAz acknowledges funding from the Gates Foundation (OPP1171700). ABad is supported by the Public Health Agency of Canada. TWB was supported by the Alexander von Humboldt Foundation through the Alexander von Humboldt Professor award, funded by the German Federal Ministry of Education and Research; the EU; the Wellcome Trust; and from National Institute of Child Health and Human Development of National Institutes of Health (NIH; R01-HD084233), National Institute on Aging of NIH (P01-AG041710), National Institute of Allergy and Infectious Diseases of NIH (R01-AI124389 and R01-AI112339), as well as Fogarty International Center of NIH (D43-TW009775). DABen was supported by the National Institute for Health Research (NIHR) Oxford Biomedical Research Centre. The views expressed are those of the authors and not necessarily those of the National Health Service, the NIHR, or the UK Department of Health and Social Care. GBB is supported by Sistema Nacional de Investigación (SNI) de la Secretaría Nacional de Ciencia, Tecnología e Innovación (SENACYT) of Panamá. FCar acknowledges UID/MULTI/04378/2019 and UID/QUI/50006/2019 support with funding from FCT/Ministério da Ciência, Tecnologia e Ensino Superior through national funds. VMC acknowledges her grant (SFRH/BHD/110001/2015), received by Portuguese national funds through Fundação para a Ciência e Tecnologia (FCT), IP, under the Norma Transitória DL57/2016/CP1334/CT0006. JDN acknowledges support from the Alexander von Humboldt Foundation. DBD acknowledges support from the Gates Foundation. KD is supported by a Wellcome Trust grant (number 201900/Z/16/Z) as part of his International Intermediate Fellowship. AGo acknowledges Sistema Nacional de Investigadores de Panamá (SNI), Secretaría Nacional de Ciencia, Tecnología e Innovación (SENACYT). CH is partly supported by a grant co-funded by European Fund for Regional Development through the Operational Program for Competitiveness (project ID P_40_382). SMSI is funded by a Fellowship from National Heart Foundation of Australia and Deakin University. MJ and the Serbian part of this GBD contribution was co-funded through grant OI175014 of the Ministry of Education Science and Technological Development of the Republic of Serbia. JK is a recipient of the 2020 Benjamin V Cohen Peace Fellowship from Ball State University Center for Peace and Conflict Studies. YJK's work was supported by the Research Management Centre, Xiamen University Malaysia, grants number XMUMRF/2018-C2/ ITCM/0001. KKr is supported by a DST PURSE grant and UGC Center of Advanced Study awarded to the Department of Anthropology, Panjab University, Chandigarh, India. BL acknowledges support from the NIHR Oxford Biomedical Research Centre and the British Heart Foundation Centre of Research Excellence, Oxford. PTNM acknowledges the Council for the Development of Social Science Research in Africa. ANA acknowledges Debre Markos University for its support in-terms of office and internet access while reviewing this paper. AMSam received a fellowship from the Egyptian Fulbright Mission programme. MMS-M acknowledges the support of the Ministry of Education, Science and Technological Development of the Republic of Serbia (contract number 175087). AShi acknowledges the support of Health Data Research UK. MRS acknowledges the Clinical Research Development Center of Imam Reza Hospital, Kermanshah university of Medical sciences for their wise advice. JBS is part of Centro de Investigación en Red de Enfermedades Respiratorias (CIBERES), Instituto de Salud Carlos III (ISCIII), Madrid, Spain. RT-S was supported in part by grant PI17/00719 from Instituto de Salud Carlos III–FEDER. BU acknowledges Manipal Academy of Higher Education, Manipal. TWij acknowledges the Migraine Foundation Australia and the Department of Medicine, Faculty of Medicine, University of Rajarata, Saliyapura, Anuradhapuraya, Sri Lanka. CSW was supported by the South African Medical Research Council. SBZ received a scholarship from the Australian Government research training program in support of his academic career.

Editorial note: the *Lancet* Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

References

1 WHO. UNICEF. Ending preventable child deaths from pneumonia and diarrhoea by 2025: the integrated Global Action Plan for Pneumonia and Diarrhoea (GAPPD). World Health Organization: Geneva, 2013. http://www.who.int/maternal_child_adolescent/documents/global_action_plan_pneumonia_diarrhoea/en/ (accessed March 10, 2020).

2 Stanaway JD, Afshin A, Gakidou E, et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; **392:** 1923–94.

3 Wolfe M, Kaur M, Yates T, Woodin M, Lantagne D. A systematic review and meta-analysis of the association between water, sanitation, and hygiene exposures and cholera in case-control Studies. *Am J Trop Med Hyg* 2018; **99:** 534–45.

4 Fewtrell L, Kaufmann RB, Kay D, Enanoria W, Haller L, Colford JM Jr. Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *Lancet Infect Dis* 2005; **5:** 42–52.

5 Moreira NA, Bondelind M. Safe drinking water and waterborne outbreaks. *J Water Health* 2017; **15:** 83–96.

6 Cairncross S, Hunt C, Boisson S, et al. Water, sanitation and hygiene for the prevention of diarrhoea. *Int J Epidemiol* 2010; **39** (suppl 1)**:** i193–205.

7 Stocks ME, Ogden S, Haddad D, Addiss DG, McGuire C, Freeman MC. Effect of water, sanitation, and hygiene on the prevention of trachoma: a systematic review and meta-analysis. *PLoS Med* 2014; **11:** e1001605.

8 Grimes JET, Croll D, Harrison WE, Utzinger J, Freeman MC, Templeton MR. The relationship between water, sanitation and schistosomiasis: a systematic review and meta-analysis. *PLoS Negl Trop Dis* 2014; **8:** e3296.

9 Grimes JE, Croll D, Harrison WE, Utzinger J, Freeman MC, Templeton MR. The roles of water, sanitation and hygiene in reducing schistosomiasis: a review. *Parasit Vectors* 2015; **8:** 156.

10 WHO. Water sanitation and hygiene for accelerating and sustaining progress on neglected tropical diseases: a global strategy 2015–2020. Geneva: World Health Organization, 2015. https://apps.who.int/iris/bitstream/handle/10665/182735/WHO_FWC_WSH_15.12_eng.pdf?sequence=1 (accessed March 10, 2020).

11 Pickering AJ, Djebbari H, Lopez C, Coulibaly M, Alzua ML. Effect of a community-led sanitation intervention on child diarrhoea and child growth in rural Mali: a cluster-randomised controlled trial. *Lancet Glob Health* 2015; **3:** e701–11.

12 Cumming O, Cairncross S. Can water, sanitation and hygiene help eliminate stunting? Current evidence and policy implications. *Matern Child Nutr* 2016; **12** (suppl 1)**:** 91–105.

13 Mbuya MNN, Humphrey JH. Preventing environmental enteric dysfunction through improved water, sanitation and hygiene: an opportunity for stunting reduction in developing countries. *Matern Child Nutr* 2016; **12** (suppl 1)**:** 106–20.

14 Sorenson SB, Morssink C, Campos PA. Safe access to safe water in low income countries: water fetching in current times. *Soc Sci Med* 2011; **72:** 1522–26.

15 Fisher J. Women in water supply, sanitation and hygiene programmes. *Proc Inst Civ Eng, Munic Eng* 2008; **161:** 223–29.

16 United Nations General Assembly. UN Resolution A/RES/64/292: the human right to water and sanitation. UN: New York, 2010. https://undocs.org/A/RES/64/292 (accessed March 10, 2020).

17 WHO UNICEF Joint Monitoring Programme. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. Geneva: WHO & UNICEF, 2017. https://www.who.int/mediacentre/news/releases/2017/launch-version-report-jmp-water-sanitation-hygiene.pdf (accessed July 13, 2020).

18 Pullan RL, Freeman MC, Gething PW, Brooker SJ. Geographical inequalities in use of improved drinking water supply and sanitation across Sub-Saharan Africa: mapping and spatial analysis of cross-sectional survey data. *PLoS Med* 2014; **11:** e1001626.

19 Lozano R, Fullman N, Abate D, et al. Measuring progress from 1990 to 2017 and projecting attainment to 2030 of the health-related Sustainable Development Goals for 195 countries and territories: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; **392:** 2091–138.

20 He W-J, Lai Y-S, Karmacharya BM, Dai B-F, Hao Y-T, Xu DR. Geographical heterogeneity and inequality of access to improved drinking water supply and sanitation in Nepal. *Int J Equity Health* 2018; **17:** 40.

21 Afifah T, Nuryetty MT, Cahyorini, et al. Subnational regional inequality in access to improved drinking water and sanitation in Indonesia: results from the 2015 Indonesian National Socioeconomic Survey (SUSENAS). *Glob Health Action* 2018; **11:** 1496972.

22 Wolf J, Prüss-Ustün A, Cumming O, et al. Assessing the impact of drinking water and sanitation on diarrhoeal disease in low- and middle-income settings: systematic review and meta-regression. *Trop Med Int Health* 2014; **19:** 928–42.

23 WHO UNICEF Joint Monitoring Programme. Progress on household drinking water, sanitation and hygiene 2000–2017: special focus on inequalities. World Health Organization and UNICEF: New York, NY, 2019. https://washdata.org/sites/default/files/documents/reports/2019-07/jmp-2019-wash-households.pdf (accessed April 24, 2020).

24 WHO UNICEF Joint Monitoring Programme. JMP methodology: 2017 update & SDG baselines. World Health Organization and UNICEF: Geneva, 2018. https://washdata.org/sites/default/files/documents/reports/2018-04/JMP-2017-update-methodology.pdf (accessed March 10, 2020).

25 WHO UNICEF Joint Monitoring Programme. Progress on sanitation and drinking water: 2015 update and MDG assessment. World Health Organization and UNICEF: Geneva, 2015. https://data.unicef.org/wp-content/uploads/2015/12/Progress-on-Sanitation-and-Drinking-Water_234.pdf (accessed July 13, 2020).

26 Wolf J, Hunter PR, Freeman MC, et al. Impact of drinking water, sanitation and handwashing with soap on childhood diarrhoeal disease: updated meta-analysis and meta-regression. *Trop Med Int Health* 2018; **23:** 508–25.

27 Golding N, Burstein R, Longbottom J, et al. Mapping under-5 and neonatal mortality in Africa, 2000–15: a baseline analysis for the Sustainable Development Goals. *Lancet* 2017; **390:** 2171–82.

28 Reiner RC Jr, Graetz N, Casey DC, et al. Variation in childhood diarrheal morbidity and mortality in Africa, 2000–2015. *N Engl J Med* 2018; **379:** 1128–38.

29 Osgood-Zimmerman A, Millear AI, Stubbs RW, et al. Mapping child growth failure in Africa between 2000 and 2015. *Nature* 2018; **555:** 41–47.

30 Graetz N, Friedman J, Osgood-Zimmerman A, et al. Mapping local variation in educational attainment across Africa. *Nature* 2018; **555:** 48–53.

31 Bhatt S, Weiss DJ, Cameron E, et al. The effect of malaria control on *Plasmodium falciparum* in Africa between 2000 and 2015. *Nature* 2015; **526:** 207–11.

32 Mosser JF, Gagne-Maynard W, Rao PC, et al. Mapping diphtheria-pertussis-tetanus vaccine coverage in Africa, 2000–2016: a spatial and temporal modelling study. *Lancet* 2019; **393:** 1843–55.

33 Murray CJL, Callender CSKH, Kulikoff XR, et al. Population and fertility by age and sex for 195 countries and territories, 1950–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; **392:** 1995–2051.

34 Stevens GA, Alkema L, Black RE, et al. Guidelines for Accurate and Transparent Health Estimates Reporting: the GATHER statement. *PLoS Med* 2016; **13:** e1002056.

35 Hosmer D, Lemeshow S, Sturdivant R. Applied Logistic Regression. Hoboken: Wiley, 2013. https://www.wiley.com/en-us/Applied+Logistic+Regression%2C+3rd+Edition-p-9780470582473 (accessed July 13, 2020).

36 Reiner RC Jr, Wiens KE, Desphande A, et al. Mapping geographical inequalities in childhood diarrhoeal morbidity and mortality in low-income and middle-income countries, 2000–2017: analysis for the Global Burden of Disease Study 2017. *Lancet* 2020; **395:** 1779–801.

37 De Maio FG. Income inequality measures. *J Epidemiol Community Health* 2007; **61:** 849–52.

38 GeoNetwork. The Global Administrative Unit Layers (GAUL). 2015. http://www.fao.org/geonetwork/srv/en/main.home (accessed June 1, 2017).

39 Land Processes Distributed Active Archive Center. Combined MODIS 5.1. MCD12Q1 LP DAAC NASA Land Data Prod. Serv. 2017. https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd12q1 (accessed June 1, 2017).

40 World Wildlife Fund. Global Lakes and Wetlands Database, Level 3. 2004. https://www.worldwildlife.org/pages/global-lakes-and-wetlands-database (accessed June 1, 2017).

41 WorldPop. WorldPop dataset. 2017. http://www.worldpop.org.uk/data/get_data/ (accessed July 24, 2017).

42 Tatem AJ. WorldPop, open data for spatial demography. *Sci Data* 2017; **4:** 170004.

43 Lehner B, Döll P. Development and validation of a global database of lakes, reservoirs and wetlands. *J Hydrol (Amst)* 2004; **296:** 1–22.

44 Luby SP, Rahman M, Arnold BF, et al. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. *Lancet Glob Health* 2018; **6:** e302–15.

45 Null C, Stewart CP, Pickering AJ, et al. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Kenya: a cluster-randomised controlled trial. *Lancet Glob Health* 2018; **6:** e316–29.

46 Humphrey JH, Mbuya MNN, Ntozini R, et al. Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on child stunting and anaemia in rural Zimbabwe: a cluster-randomised trial. *Lancet Glob Health* 2019; **7:** e132–47.

47 Lim SS, Updike RL, Kaldjian AS, et al. Measuring human capital: a systematic analysis of 195 countries and territories, 1990–2016. *Lancet* 2018; **392:** 1217–34.

48 Hutton G. Global costs and benefits of reaching universal coverage of sanitation and drinking-water supply. *J Water Health* 2013; **11:** 1–12.

49 McGahey C. Africa, WASH, and the Millennium Development Goals: a local systems case study of how Ethiopia achieved MDG Target 7c. USAID: Washington, DC, 2017. https://files.globalwaters.org/water-links-files/WALIS%20-%20Local%20System%20Case%20Study%20-%20Ethiopia%20-%20FINAL.pdf (accessed July 13, 2020).

50 Wilder M. The human right to water in Mexico: challenges and opportunities. *Water Altern* 2020; **13:** 28–48.

51 Mason N, Mosello B. How to reduce inequalities in access to WASH. London: Overseas Development Institute, 2017. https://www.odi.org/sites/odi.org.uk/files/resource-documents/11604.pdf (accessed July 13, 2020).

52 Adhikari AK, Acharya HN, Ahmad T, Shrestha S. Innovative sanitation social movement: experiences from Nepal. In: Local action with international cooperation to improve and sustain water, sanitation and hygiene (WASH) services. Loughborough University Institutional Repository: Loughborough, UK, 2017. https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/31419 (accessed March 10, 2020).

53 Sarwar MB, Mason N. How to reduce inequalities in access to WASH: rural water and sanitation in Nepal. London: Overseas Development Institute https://www.odi.org/sites/odi.org.uk/files/resource-documents/11607.pdf (accessed April 27, 2020).

54 Mosello B, O'Leary D. How to reduce inequalities in access to WASH: urban sanitation in Cambodia. London: Overseas Development Institute https://www.odi.org/sites/odi.org.uk/files/resource-documents/11605.pdf (accessed April 27, 2020).

55 Smets S. Water supply and sanitation in Cambodia: turning finance into services for the future. International Bank for Reconstruction and Development, The World Bank: Washington, DC, 2015. http://documents.worldbank.org/curated/en/545311468178454239/pdf/100889-WSP-P131116-AUTHOR-Susanna-Smets-Box393244B-PUBLIC-WSP-SERIES-Cambodia-WSS-Turning-Finance-into-Service-for-the-Future.pdf (accessed April 27, 2020).

56 McDonald RI, Weber K, Padowski J, et al. Water on an urban planet: urbanization and the reach of urban water infrastructure. *Glob Environ Change* 2014; **27:** 96–105.

57 Luby SP, Rahman M, Arnold BF, et al. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. *Lancet Glob Health* 2018; **6:** e302–15.

58 Graham JP, Polizzotto ML. Pit latrines and their impacts on groundwater quality: a systematic review. *Environ Health Perspect* 2013; **121:** 521–30.

59 Bain R, Cronk R, Wright J, Yang H, Slaymaker T, Bartram J. Fecal contamination of drinking-water in low- and middle-income countries: a systematic review and meta-analysis. *PLoS Med* 2014; **11:** e1001644.

60 World Bank Group. Reducing inequalities in water supply, sanitation, and hygiene in the era of the Sustainable Development Goals: synthesis report of the WASH Poverty Diagnostic Initiative. World Bank: Washington, DC, 2017. https://doi.org/10.1596/27831 (accessed July 13, 2020).

61 Ghobarah HA, Huth P, Russett B. The post-war public health effects of civil conflict. *Soc Sci Med* 2004; **59:** 869–84.

62 Local Burden of Disease Diarrhoea Collaborators. Mapping geographical inequalities in oral rehydration therapy coverage in low-income and middle-income countries, 2000–17. *Lancet Glob Health* 2020; **8:** e1038–60.

63 WHO. WASH and health working together: a 'how-to' guide for neglected tropical disease programmes. World Health Organization: Geneva, 2018. https://apps.who.int/iris/bitstream/handle/10665/279913/9789241515009-eng.pdf?ua=1 (accessed March 10, 2020).

64 Freeman MC, Ogden S, Jacobson J, et al. Integration of water, sanitation, and hygiene for the prevention and control of neglected tropical diseases: a rationale for inter-sectoral collaboration. *PLoS Negl Trop Dis* 2013; **7:** e2439.

65 Stocks ME, Freeman MC, Addiss DG. The effect of hygiene-based lymphedema management in lymphatic filariasis-endemic areas: a systematic review and meta-analysis. *PLoS Negl Trop Dis* 2015; **9:** e0004171.

66 Sikorski C, Ashine M, Zeleke Z, Davey G. Effectiveness of a simple lymphoedema treatment regimen in podoconiosis management in southern ethiopia: one year follow-up. *PLoS Negl Trop Dis* 2010; **4:** e902.

67 International Trachoma Initiative. Trachoma atlas. 2018. http://www.trachomaatlas.org/ (accessed March 10, 2020).